GEORGIA INSTITUTE OF TECHNOLOGY — OFFICE OF CONTRACT ADMINISTRATION

PROJECT ADMINISTRATION DATA SHEET

[X] ORIGINAL [ ] REVISION NO. ______

Project No. E-25-K01 (R5913-0A0) GTRC/~~XXXX~~ DATE 3 / 22 / 85

Project Director: Dr. Melvin W. Carter School/~~XXX~~ ME/NE

Sponsor: U. S. Environmental Protection Agency

Type Agreement: Cooperative Agreement No. CR 812164-01-0

Award Period: From 3/18/85 To 1/17/86 (Performance) 9/17/86 (Reports)

Sponsor Amount:

	This Change	Total to Date
Estimated:	$ 88,884	$ 88,884
Funded:	$ 88,884	$ 88,884

Cost Sharing Amount: $ 4,679 Cost Sharing No: E-25-326 (F5913-0A0)

Title: Health and Environmental Effects Assessment of Synfuels

ADMINISTRATIVE DATA

OCA Contact Brian J. Lindberg X4820

1) Sponsor Technical Contact:

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Office of Research and Development (RD-682)
Environmental Protection Agency
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Defense Priority Rating: N/A

Military Security Classification: N/A
(or) Company/Industrial Proprietary: N/A

RESTRICTIONS

See Attached EPA Supplemental Information Sheet for Additional Requirements.

Travel: Foreign travel must have prior approval — Contact OCA in each case. Domestic travel requires sponsor approval where total will exceed greater of $500 or 125% of approved proposal budget category.

Equipment: Title vests with None propsoed or anticipated.

COMMENTS:

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Accounting	Research Communications (2)	Other Jones

FORM OCA 65:285

GEORGIA INSTITUTE OF TECHNOLOGY OFFICE OF CONTRACT ADMINISTRATION

SPONSORED PROJECT TERMINATION/CLOSEOUT SHEET

Date 11/26/86

Project No. E-25-K01 School/~~Lab~~ ME/NE

Includes Subproject No.(s) N/A

Project Director(s) Dr. Melvin W. Carter GTRC / ~~GIT~~

Sponsor U. S. Environmental Protection Agency

Title Health and Environmental Effects Assessment of Synfuels

Effective Completion Date: 11/17/86 (Performance) ______ (Reports)

Grant/Contract Closeout Actions Remaining:

- [ ] None
- [x] Final Invoice or Final Fiscal Report
- [ ] Closing Documents
- [ ] Final Report of Inventions
- [ ] Govt. Property Inventory & Related Certificate
- [ ] Classified Material Certificate
- [ ] Other ______

Continues Project No. ______ Continued by Project No. ______

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Other I. Newton
A. Jones
R. Embry

FORM OCA 69.285

REPORT OF THE

PEER REVIEW GROUP

FOR THE INTEGRATED HEALTH AND ENVIRONMENTAL

RISK ANALYSIS PROGRAM

FOR THE

U.S. ENVIRONMENTAL PROTECTION AGENCY

INTEGRATED HEALTH AND ENVIRONMENTAL RISK ANALYSIS

PROGRAM FOR SYNFUELS

MEETING HELD AT

KNOXVILLE, TENNESSEE

NOVEMBER 18-19, 1981

REPORT DATE

JANUARY, 1982

REPORT OF THE PEER REVIEW GROUP FOR THE INTEGRATED HEALTH AND ENVIRONMENTAL RISK ANALYSIS PROGRAM

PURPOSE

The objective of this report is to summarize the results of a review of the Environmental Protection Agency (EPA) Integrated Risk Analysis for Synfuels Program which was conducted during November, 1981, by a Peer Review Group established for this purpose. The members of the Peer Review Group are listed in Attachment 1.

PROCEDURES

Members of the Peer Review Group were provided with several draft documents which were prepared by pertinent researchers at the Oak Ridge National Laboratory, Health and Safety Research Division and the Environmental Sciences Division. These documents are identified in Attachment 2 and were furnished prior to the review meeting.

A review meeting was held on November 18-19, 1981, in Knoxville, TN. At that time, relevant researchers presented reports on the status, progress, and plans for their research. The agenda for the Peer Review Meeting is included as Attachment 3, whereas, the list of participants is Attachment 4.

This report is based on the briefings and discussion which occurred on November 18-19 and on comments furnished by members of the Peer Review Group who could not participate in the meeting but did read the referenced documents.

COMMENTARY

Commentary is presented under the headings of Exposure Assessment, Health Effects Assessment, Environmental Effect Assessment, and General Comments. Following the concise commentary is a brief section containing relevant recommendations.

EXPOSURE ASSESSMENT

Oak Ridge National Laboratory (ORNL) has selected its own models for the determination of exposure to airborne contaminants because they are available and reasonably well understood. In the utilization of these models several questions must be raised.

1. The effective ability to deal with chemical transformation (e.g., photochemical oxidation) during the transport process (long and short term) is important and must be developed, especially, for periods of about 24 hours and less. In accounting for the wide diurnal fluctuations in (OH) and (O_3) it is suggested that use of simple trajectory models can produce diurnal (OH) and (O_3) values for typical urban and rural scenarios. The outlined approach is laudable and worth exploring for longer time averages such as annual and seasonal.
2. Model validation is of utmost importance and is dependent upon complexity of the model and the currently available data base.
3. Models should be as simple as possible to obtain the needed information and data. Complexity should be added only when it is needed to achieve needed results.

4. Model calculations, based on reciprocal averages of wind velocities when using the STAR data base, must be justified as plume rise, dispersion, and other parameters are not independent variables as to variations in wind velocity.
5. Applicability of the ORNL model at distances of 100 km is questionable. Similar models for dispersion have not been certified by EPA for more than 50 km from the source.
6. The present inability to utilize complex terrain is a serious limitation. Particular models consider certain limited aspects of complex terrain, e.g., elevated terrain extending into the plume, but not effects of such terrain on three-dimensional wind fields and related consequences of pollutant dispersion.
7. Risk, and its analysis depend upon interaction of the pollutant and the sensitive receptors (people), the exposure levels, the numbers of people affected, and the exposure times. Thus, most probable exposures should be analyzed as well as worst case exposures.
8. Worst case characteristics should be based on worst day meteorological conditions. This can be done with use of worst 24-hour sequences from a CRSTER type analysis or use of worst case data to define relative frequencies of joint occurrences of meteorological inputs for a climatological algorithm such as AIRDOS.

9. Risk analysis must be able to account for increases in pollution, changes in distribution patterns, and other related factors caused by the siting of a synfuel plant at a particular site.
10. It is imperative that models be tested in as practical a manner as possible, and the selection for testing should be based on a priority system.

HEALTH EFFECTS ASSESSMENT

This difficult problem of estimating the magnitude and uncertainties of possible health effects from synfuels production and use on humans is compounded by the lack of relevant clinical data and the absence of an acceptable human model. Several areas are outlined for additional consideration.

1. The particular assay strategy for carcinogenicity should be selected and discussed as to the tests to be employed for different classes of chemicals, in what sequences, and the respective rationales.
2. Animal data, such as bioassays, are useful in assessing health effects of synfuels. Better perspective is needed in references to the work of Roe and Tucker.
3. The testing strategy for reproductive toxicity and the description of the relevant dose-effect extrapolation models need to be discussed on a more explicit basis.

4. Methodology, using the concept of relative potency factors and relative effects, is a reasonable approach to estimating potential health risks of synfuel derived pollutants.
5. It is important to evaluate or verify this model using available data. Hopefully, data are available to permit a full exploration of the uncertainties involved in such an analysis.
6. The principal thrust of the model should be to produce timely and valid estimates of the effects of the process being modeled. A correlative statement would be that simple models are more easy to validate than more complex ones.
7. Model validation at a single site using an EPA defined source term should take precedent over more complex model development. For example, it may well be necessary to simplify the model based on validation trials subsequent to the demonstration of its scientific validity as to the original approach.
8. Health effects should be broader than carcinogenicity and reproductive effects or the rationale should be presented for their exclusion.

ECOLOGICAL ASSESSMENT

Assessment in the area of environmental risk is also complex, must deal with a wide variety of compounds, must be capable of handling transformation products, and is plagued by a lack of specific data needed for verification. However, the current methodology offers analytical promise.

1. An important need is to establish more specific end points rather than those of a global nature.
2. Related to item 1 would be the establishment of a system to set priorities, i.e., what are the important issues.
3. For a number of cogent reasons, it is doubtful that generic assessment of risk is practicable.
4. The degree of complexity in the model should "fit" the current situation and be formulated to take advantage of the available data.
5. The method outlined for isolating parametric uncertainties and the modified "Delphic" approach to provide expert input appear to be useful.
6. A selected model should be tested for applicability, determination of uncertainties, and flexibility as to iterative upgrading.

GENERAL COMMENTS

Risk Assessment is a relatively new field and in many areas has not been used extensively. It has great promise and needs to be defined and documented as an inherent part of its development.

1. Agreement on definitions and standardized terminology are needed. Examples would be risk assessment, distinction between exposure and dose, and relative potency factor.

2. The role of models, in our context, is to develop a methodology which is scientifically acceptable and can be used to estimate effects which will aid the EPA in establishing regulations for a synthetic fuels industry.
3. Research goals should, whenever possible, be defined precisely, explicitly, practically, and simply.
4. Research reports should read more like a description of research accomplished rather than a research proposal for funding.
5. Estimation and appropriate characterization of synfuel source terms should be given attention and consideration commensurate with knowing these parameters when they are needed.
6. Parallel with item 5, work should be directed at characterization of effluent mixtures in terms of Process Parameter Products. This would include process parameters, type and extent of processing, and effects of control treatment.
7. Rough estimates of effects to be expected should be made. These may be for "internal use only" but would be useful for getting a feel for their magnitude.
8. Model development should proceed just far enough to obtain timely and accurate data when the model is applied to the real problem.
9. Model testing is just as important (perhaps more so) as model development. It should be approached on an experimental basis.

RECOMMENDATIONS

In addition to previous comments offered for consideration, the Peer Review Group makes the following recommendations:

1. Support the development and peer review of a standardized glossary of terms, terminology, and procedures for risk assessment.

2. Move as quickly as possible to the "real world" testing of simplified models. Major steps in this process would involve:

   a. Simplify the exposure and health effects models as suggested.

   b. Select one of the three technologies for use in model experimental application.

   c. Define a source term for the selected case.

   d. Develop the data needed to apply the model to the test case.

   e. Apply the simplified model.

   f. Perform sufficient sensitivity runs to understand the model and its weaknesses.

   g. As resources permit, improve the model based on results of the sensitivity runs.

This approach should produce a practical and better model fairly quickly and not be too encumbered with sophisticated model technology development.

ATTACHMENT 1

PEER REVIEW GROUP MEMBERS
FOR THE INTEGRATED HEALTH AND ENVIRONMENTAL RISK ANALYSIS FOR SYNFUELS
NOVEMBER 18-19, 1981

CHAIRMAN

Professor Norman C. Rasmussen
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National Institute of Environmental Health Sciences
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Dr. Louie E. Furlong, Manager
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Dr. G. K. Vick (Alternate for Dr. Furlong)
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Arthur C. Upton, M.D., Chairman and Professor
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Dr. Burton E. Vaughan, Manager
Ecological Sciences Department
Battelle PNL
Richland, WA 99352

EXECUTIVE DIRECTOR

Dr. Melvin W. Carter, Neely Professor
School of Nuclear Engineering and Health Physics
Georgia Institute of Technology
Atlanta, GA 30332

ATTACHMENT 2

PEER REVIEW GROUP
REFERENCED DOCUMENTS

1. "Methodology for Health Effects Assessment of Synfuels Technologies", E. E. Calle, C.S. Dudney, G. D. Griffin, T. D. Jones,and M. Uziel, ORNL, Draft.
2. "Exposure Assessment Methodology for Synfuels Technologies", C. C. Travis, S. J. Gull, G. A. Holton, and A. P. Watson, ORNL, Draft.
3. "Methodology for Environmental Risk Assessment of Synfuels Technologies", L. W. Barnthouse, D. L. DeAngelis, R. H. Gardner, R. V. O'Neill, C. D. Powers, G. W. Suter II, and D. S. Vaughan, ORNL, Draft.
4. "Generic Environments for Synfuels Risk Assessments", S. J. Gull and G. W. Suter, II, ORNL, Draft.

These Reference Materials are contained in the Project Files.

ATTACHMENT 3
AGENDA FOR THE
PEER REVIEW GROUP
INTEGRATED HEALTH AND ENVIRONMENTAL RISK ANALYSIS PROGRAM

WEDNESDAY, NOVEMBER 18, 1981

11:00	Introduction and Opening Discussion	A. A. Moghissi, ORD/EPA
12:00	LUNCH	
1:00	Exposure Assessment	
1:15	Atmospheric Transport and Transformation	G. A. Holton
2:00	Aquatic Transport Food Chain Transport Generic Site Description	S. J. Gull
2:45	Discussion	

THURSDAY, NOVEMBER 19, 1981

9:00	Overview	P. J. Walsh
9:15	Health Effects Assessment Methods	E. E. Calle
10:00	Carcinogenesis Application	G. D. Griffin
11:15	Discussion	
12:00	LUNCH	
1:00	Overview of Environmental Risk	C. W. Gehrs
1:30	Part I - Quotient Method Extrapolation of Error	G. W. Suter
2:15	Part II - Fault Three Analysis Analytical Hierarchy Ecosystem Uncertainty Analysis	L. W. Barnthouse
3:00	Discussion	

* Agenda lists major presenters. Other technical staff will present/discuss as necessary.

ATTACHMENT 4

PEER REVIEW GROUP MEETING PARTICIPANTS

Larry Barnthouse, Oak Ridge National Laboratory
Jeanne Calle, Oak Ridge National Laboratory
Melvin W. Carter, Georgia Institute of Technology
Charles S. Dudney, Oak Ridge National Laboratory
Clay Easterly, Oak Ridge National Laboratory
C. W. Gehrs, Oak RIdge National Laboratory
Stanley Greenfield, Systems Applications, Inc.
S. J. Gull, Oak Ridge National Laboratory
Gregory A. Holton, Health and Safety Research Division
Seymour Holtzman, U.S. Environmental Protection Agency
Stephen V. Kaye, Oak Ridge National Laboratory
Michael P. Maskarinec, Oak Ridge National Laboratory
A. Alan Moghissi, U.S. Environmental Protection Agency
Sam Morris, Brookhaven National Laboratory
Dennis Parzyck, Oak Ridge National Laboratory
Maria Pavlova, U.S. Environmental Protection Agency
Norman C. Rasmussen, Massachusetts Institute of Technology
Glenn W. Suter, II, Oak Ridge National Laboratory
Curtis Travis, Oak Ridge National Laboratory
M. Uziel, Oak Ridge National Laboratory
Gerald K. Vick, Exxon Research and Engineering Company
P. J. Walsh, Oak Ridge National Laboratory
Elaine Zeighami, Oak Ridge National Laboratory

REPORT OF THE

PEER REVIEW PANEL

ON HUMAN EFFECTS OF SYNFUEL PRODUCTION

FOR THE

U.S. ENVIRONMENTAL PROTECTION AGENCY

INTEGRATED HEALTH AND ENVIRONMENTAL RISK ANALYSIS

PROGRAM FOR SYNFUELS

MEETING HELD AT

BROOKHAVEN NATIONAL LABORATORY

UPTON, NEW YORK

MAY 6, 1982

REPORT DATE

JUNE, 1982

REPORT OF THE PEER REVIEW PANEL ON HUMAN HEALTH EFFECTS OF SYNFUEL PRODUCTION

PURPOSE

The objective of this report is to summarize the results of a peer review of the U.S. Environmental Protection Agency's research effort in the area of Human Health Effects of Synfuel Production. The review was conducted on May 6, 1982, at the Medical Department of the Brookhaven National Laboratory by a Peer Review Panel established for this purpose. Members of the Peer Review Panel are listed in Attachment 1.

PROCEDURE

Prior to the meeting on May 6, members of the Peer Review Panel were furnished with copies of the document "Assessment of Exposure Relationships of Chemicals Representing Risk Analysis Units to Human Health". This information was provided by Dr. Marilyn E. Miller, Medical Department, Brookhaven National Laboratory, and a copy is enclosed as Attachment 2.

The agenda for the meeting is shown as Attachment 3; whereas, a list of participants is included as Attachment 4. Other relevant information distributed during the Peer Review Panel meeting is identified in Attachment 5.

COMMENTARY

The commentary and recommendations are based on the briefings and presentations at the Peer Review Panel meeting and on review of the several documents which were furnished to members of the Panel.

Objectives of these proposed studies are to develop and use laboratory indices for the assessment of potential health impacts of exposure of workers to chemical agents associated with the production and processing of synfuels. Populations of workers selected for study are those actively or previously employed in the synfuel industry or in industrial activities having working environments closely similar to those encountered in the synfuel industry; i.e., exposures to similar chemical agents.

Laboratory indices proposed for use include:

1. DNA damage - to be assessed by frequency of chromosome aberrations, sister chromatid exchanges, micronuclei, and thioguanine resistance in peripheral blood lymphocytes.
2. Abnormalities of hemopoietic stem cells -- to be analyzed through studies of colony formation on aspirated specimens of bone marrow.
3. Impaired respiratory function -- to be determined by pulmonary function tests and lung scans.

The research team has experience in the application of these research approaches and has special expertise in hematology, cytogenetics, and nuclear medicine. The level of competence is also well above average in the proposed clinical and laboratory studies of the study populations.

In addition to the development and application of these laboratory indices it is critically important that they be appropriately applied to pertinent study populations. The primary purpose of the research effort is to determine if such indices can serve on a predictive basis to identify potential adverse human health effects in exposed workers. Thus, the selection of study groups requires careful attention to the numbers of individuals, the amounts and natures of their exposures and their continuing availability for investigative research.

Certain areas in this proposed effort should be given particular care and attention and include:

1. Particular definition of the study groups and any constraints as well as estimation of the health effects risks.
2. The cooperation of management and the workers in each of these proposed study groups.
3. The time required to develop the needed data base for short-term exposures; especially applicable to the Cleveland coke oven group.
4. The need to develop effective detailed protocols and capabilities for the determination of occupational exposure profiles and their specific correlation with RAU's.
5. The extreme importance of quantifying the similarities and differences between the synfuels and surrogate processes, workers, and exposures in terms of RAU's, respectively.
6. Constraint in the numbers and diversity of laboratory indices to be studied due to the lack of specificity.

7. The amounts and kinds of biases which can be introduced into results obtained in working with a volunteer population.
8. Identification of information which could be used to address the possible problem of reproductive risk.
9. Inherent problems in epidemiological studies such as their unwieldiness for predictive purposes.

RECOMMENDATIONS

These health effects studies on relevant groups of workers appear to be timely and meritorious in developing and applying laboratory indices in the evaluation of potential health impacts from exposure to certain chemical agents, and should be pursued with carefully selected and characterized populations.

The definition and constraints on use of surrogate parameters should be quantified and qualified with deliberate care.

A detailed protocol needs to be prepared for the measurement (determination) of occupational exposure profiles. Exposure assessment must be based on analyses of relevant samples collected from the work environment, and exposures must be expressed in pertinent RAU's. It would also be of interest to investigate benzo (a) pyrene-DNA adduct formation in the workers' sputum cells and white blood cells in relation to data on their ambient exposure levels (see Perera and Weinstein, J. Chrom. Dis. 35:581-600, 1982) as a potential biochemical dosimeter to aid in exposure assessment.

Results of these health effects studies should be evaluated in terms of their contributions to the development of risk assessment methodologies needed for quantitative and predictive use in the future as well as their applicability to the currently identified questions.

ATTACHMENT 1

PEER REVIEW PANEL MEMBERS
HUMAN HEALTH EFFECTS OF SYNFUEL PRODUCTION
BROOKHAVEN NATIONAL LABORATORY
MAY 6, 1982

CHAIRMAN

Arthur C. Upton, M.D.
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Steve Blum, Ph.D.
The New York Hospital
Cornell Medical Center
Department of Public Health
525 East 68th Street
New York, New York 10021

ATTACHMENT 2

Document "Assessment of Exposure Relationships of Chemicals Representing Risk Analysis Units to Human Health". This document was furnished to Members of the Peer Review Panel before the Review Meeting. It is contained in the Project Files.

ATTACHMENT 3

AGENDA FOR THE PEER REVIEW PANEL ON HUMAN HEALTH EFFECTS OF SYNFUEL PRODUCTION

BROOKHAVEN NATIONAL LABORATORY
MAY 6, 1982

1000	Introduction	Dr. Alan Moghissi
1015	Background and Objectives	Marilyn E. Miller
1025	Population Selection Study Design	Jerome Barancik Samuel Morris
1100	Occupational Exposure Profiles	Otto White
1115	General Outline of Studies Performed at the Medical Research Center, BNL	Marilyn E. Miller
1130	Statistical Methods to be Used to Analyze Data	Henry Thode
1200	Lunch	
1300	Methods To Be Used To Study A. DNA Damage	 Michael Bender
1320	Hemopoetic Progenitor Cell Damage	Marilyn E. Miller
1330	Respiratory Damage	A. B. Brill
1400	Complementary BNL Studies	Eugene P. Cronkite Leonard Hamilton
1430	General Discussion	

ATTACHMENT 4

PARTICIPANTS
HUMAN HEALTH EFFECTS OF SYNFUEL PRODUCTION
MAY 6, 1982

Dr. Steven Blum, Cornell University
Dr. M. W. Carter, Georgia Institute of Technology
Dr. Robert Goldsmith, Department of Energy
Dr. Seymour Holtzman, Environmental Protection Agency, ORD
Dr. A. A. Moghissi, Environmental Protection Agency
Dr. Vaun Newill, Exxon Corporation
Dr. Maria Pavlova, Environmental Protection Agency
Dr. Jacob W. Thiessen, Department of Energy
Dr. Arthur Upton, New York University Medical Center
Dr. Joseph Costello, National Institute of Occupational Safety & Health
Dr. Steve Resnik, National Institute of Occupational Safety & Health
Marilyn E. Miller, Brookhaven National Laboratory
Eugene P. Cronkite, Brookhaven National Laboratory
M. A. Bender, Brookhaven National Laboratory
Jerome Baranick, Brookhaven National Laboratory
Leonard Hamilton, Brookhaven National Laboratory
Samuel Morris, Brookhaven National Laboratory
Henry Thode, Brookhaven National Laboratory
Otto White, Brookhaven National Laboratory
A. Brill, Brookhaven National Laboratory
V. P. Bond, Brookhaven National Laboratory
D. C. Borg, Brookhaven National Laboratory
R. B. Aronson, Brookhaven National Laboratory

ATTACHMENT 5

Reference materials distributed during the Review Meeting. These are contained in the Project Files.

REPORT OF THE
PEER REVIEW PANEL
ON THE FOOD CHAIN TRANSPORT OF SYNFUELS

FOR THE

U.S. ENVIRONMENTAL PROTECTION AGENCY

INTEGRATED HEALTH AND ENVIRONMENTAL RISK ANALYSIS

PROGRAM FOR SYNFUELS

MEETING HELD AT

COMPARATIVE ANIMAL RESEARCH LABORATORY

OAK RIDGE ASSOCIATED UNIVERSITIES

OAK RIDGE, TENNESSEE

MAY 18, 1982

REPORT DATE

JULY, 1982

REPORT OF THE PEER REVIEW PANEL ON FOOD CHAIN TRANSPORT OF SYNFUELS

PURPOSE

The objective of this report is to summarize the results of a peer review of the U.S. Environmental Protection Agency's research effort in the area of Food Chain Transport of Synfuels. This review was conducted on May 18, 1982 at the Comparative Animal Research Laboratory in Oak Ridge, TN by a Peer Review Panel established for this purpose. Members of the Peer Review Panel are listed in Attachment 1.

PROCEDURE

Before the meeting on May 18, members of the Peer Review Panel were provided with copies of the document "Food Chain Transport of Synfuels". This material was furnished by Dr. G. R. Eisele of the Comparative Animal Research Laboratory and a copy is enclosed as Attachment 2.

The agenda for the meeting is shown as Attachment 3 and a listing of participants is included as Attachment 4. Attachment 5 includes other pertinent information which was distributed to participants during the meeting of the Peer Review Panel.

COMMENTARY

The several goals of this research effort are to determine if potentially toxic materials from synfuels accumulate or persist through the food chain using animal studies and plant studies coupled with analytical methodology. The emphasis is on food-producing animals.

In such a complex undertaking, questions arise primarily in the selection of research priorities and in the methodological approaches adopted in pursuing these tasks within the constraints imposed by resource allocations. Additional concerns relate to other interdependent parts of the total research program such as effective characterization of RAU's and appropriate selection of representative compounds for RAU's and the rationale upon which these important decisions are based.

There is a general consensus that the research facilities available at the Comparative Animal Research Laboratory are adequate for these research activities and that the pertinent research staff is experienced in the application of scientific expertise to the technical problems posed in the research protocol.

There are several basic questions regarding methodologies and anticipated results of the research which need to be given careful attention. These include:

1. Whether or not the number of chemicals (compounds) selected for study is suitable for the resources available? This obviously involves a balance between developing satisfactory information for each compound vs. accumulating incomplete research results.
2. Whether or not the expected experimental data can be appropriately extrapolated from the exposure - accumulation food chain domain to the environmental setting wherein synfuel products would be introduced?

3. Whether or not the basic assumptions that loss of radioactivity label translates directly into loss of parent compound and thus loss of "adverse properties"?

4. Whether or not sufficient "science" can be built into research efforts which are inherently designed to produce data in selected areas which are needed as background for decision making in certain areas of risk and analysis?

5. Whether or not a more restricted and thus more detailed procedure might provide more useful information on a timely basis?

The answers to such questions involve scientific considerations but also have important elements of Agency and program needs, available resources, relationships with relevant research in other parts of the Agency and other groups, and pertinent priorities.

More specific questions relate to the time intervals selected for the uptake and retention studies of naphthalene, etc. and the interpretation of certain experimental data. For example, in Table 4 (Food Chain Transport of Synfuels) why are naphthalene concentrations higher in the pig tissues than in the dairy cow and the hen? Similarly, another explanation for the effect noted (Figure 6 and discussed on page 24 of Food Chain Transport of Synfuels) of low concentration of naphthalene in fat of swine in chronic exposure experiments is that the data reflect equilibrium between blood and adipose tissue, metabolism, and then their excretion.

RECOMMENDATIONS

This research program should be continued with a careful assessment devoted to the objectives expected to be obtained within a prescribed period and the other management constraints.

Consideration be given to acquiring uptake/retention data at additional time increments for each animal species. These additional data sets would be most valuable in interpreting research results for application to risk assessment.

The desirability and need to monitor parent compound concentrations throughout these uptake/retention studies. Reasonable approaches for this should be evaluated.

Need to assess metabolic products of parent compounds that are administered to plants or animals. It is essential to consider the organic residuals left behind after the radioactive label disappears from a parent compound. Reasonable approaches should be evaluated, including direct chemical measurement.

Need to consider the importance of evaluating aerial deposition and foliar uptake mechanisms by plants. These data are needed to complement root uptake information. A companion determination would be related to the tenacity of plant surfaces for absorbed compounds.

Other future plant studies which need to be kept in mind concern the roles and kinetics of soil microfloral populations in plant metabolism of deposited RAU compounds, and the need to evaluate the environmental pathway represented by use of contaminated plants by food-producing animals.

Emphasis be given to the critical role of coordination and communication in this research program which of necessity represents a diverse and complex undertaking. Thus, all elements of the research program should be encouraged and urged to communicate freely, effectively, and frequently.

ATTACHMENT 1

PEER REVIEW PANEL MEMBERS
FOOD CHAIN TRANSPORT OF SYNFUELS

MAY 18, 1982

CHAIRMAN

Dr. Burton E. Vaughan, Manager
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Dr. George W. Lucier, Head
Receptor Pharmacology Section
Laboratory of Pharmacology
National Institute of Environmental Health Sciences
Department of Health and Human Services
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Research Triangle Park, NC 27709

ATTACHMENT 2

The document "Food Chain Transport of Synfuels" was distributed to Panel Members before the Panel Meeting. It is contained in the Project Files.

ATTACHMENT 3

AGENDA FOR THE PEER REVIEW PANEL ON FOOD CHAIN TRANSPORT OF SYNFUELS OAK RIDGE, TN

MAY 18, 1986

9:00	Arrival and tour of CARL	
10:30	Introduction and Welcome	W. E. Felling Acting Director, ORAU
10:45	Introduction of Food Chain Program	A. A. Moghissi, EPA
11:15	Overview of Food Chain Program	H. E. Walburg, Director, CARL
11:45	Lunch	
12:30	Review of Animal Project	G. R. Eisele, CARL
1:00	Review of Plant Project	O. J. Schwarz, UT/CARL
1:30	Review of Chemistry Project	T. D. Traylor, CARL
2:00	Discussions	

MAY 19, 1986

9:00	Further discussions of research with investigators, as required	G. R. Eisele O. J. Schwarz T. D. Traylor H. E. Walburg

ATTACHMENT 4

PARTICIPANTS

FOOD CHAIN TRANSPORT OF SYNFUELS
OAK RIDGE, TN
May 18-19, 1986

James T. Stemmle, Environmental Protection Agency

M. W. Carter, Georgia Institute of Technology

G. R. Eisele, Comparative Animal Research Laboratory

T. Dennis Traylor, Comparative Animal Research Laboratory

Robert J. Chertok, Comparative Animal Research Laboratory

George Lucier, National Institute of Environmental Health & Safety

Allan Isensee, Department of Agriculture

Burton E. Vaughan, Battelle Pacific Northwest Laboratory

James L. Epler, Oak Ridge National Laboratory

Carl W. Gehrs, Oak Ridge National Laboratory

Fred Baes, Oak Ridge National Laboratory

Steve Hilderbrand, Oak Ridge National Laboratory

Glenn Suter, Oak Ridge National Laboratory

Mike Guerin, Oak Ridge National Laboratory

Alan Moghissi, Environmental Protection Agency

Seymour Holtzman, Environmental Protection Agency

H. E. Walburg, Comparative Animal Research Laboratory

Otto J. Schwarz, Comparative Animal Research Laboratory

ATTACHMENT 5

Reference materials distributed during the Meeting of the Peer Review Panel. These materials are contained in the Project Files.

REPORT OF THE

PEER REVIEW GROUP

ON THE INTEGRATED HEALTH AND ENVIRONMENTAL

RISK ANALYSIS PROGRAM FOR SYNFUELS

FOR THE

U.S. ENVIRONMENTAL PROTECTION AGENCY

INTEGRATED HEALTH AND ENVIRONMENTAL RISK ANALYSIS

PROGRAM FOR SYNFUELS

MEETING HELD AT

ALEXANDRIA, VIRGINIA

MARCH 28-29, 1983

REPORT DATE

APRIL, 1983

REPORT OF THE PEER REVIEW GROUP ON THE INTEGRATED HEALTH AND ENVIRONMENTAL RISK ANALYSIS PROGRAM FOR SYNFUELS

PURPOSE

The objective of this report is to summarize the results of a review of the Environmental Protection Agency (EPA) Integrated Risk Analysis for Synfuels Program. The review was conducted on March 28 and 29, 1983 by a Peer Review Group established for this purpose. The members of the Peer Review Group are listed in Attachment 1.

PROCEDURE

Members of the Peer Review Group were provided with several draft documents prior to the review meeting. These documents were prepared by researchers at the Oak Ridge National Laboratory, Environmental Sciences Division, and are identified in Attachment 2. In addition, the Group was provided with additional documents, at the review meeting, prepared by researchers at the Brookhaven National Laboratory. These documents are also identified in Attachment 2.

The agenda for the Peer Review meeting is included as Attachment 3 and the list of participants appears in Attachment 4.

COMMENTARY

Each of the groups involved in this program made an in-depth presentation at the Review meeting and was subjected to intensive questioning. Following the formal meeting the Peer Review Group individually provided a detailed written set of comments. This report represents a summary of the reviewer's comments. No attempt was made to report every comment of each review. Rather, an attempt was made to provide a sense of the Review Group's findings. This report should not be construed as necessarily representing a consensus of the Group. Where important minority comments are provided they have been included.

ENVIRONMENTAL ASSESSMENT

The environmental segment of EPA's Integrated Risk Assessment for Synfuels has been underway at Oak Ridge National Laboratory (ORNL) since 1981. For the purpose of their analysis ORNL selected five environmental end points:

1. Reductions in abundance and production of commercial or game fish populations.
2. Development of algal populations that detract from water use.
3. Reductions in timber production.
4. Reductions in agricultural production.
5. Reductions in wildlife population.

Five models or methodologies were employed to perform or address the analysis of risk.

1. Quotient method (QA).
2. Analysis of extrapolation error (AEE).
3. Analytic hierarchy method (AHM).

4. Ecosystem uncertainty analysis (EUA).

5. Fault tree analysis (FTA).

For this study ORNL derived aquatic and atmospheric source terms by characterizing the process and waste streams from a hypothetical Lurgi/Fischer-Tropsch indirect coal liquefaction plant. Because of the extremely large number of chemical compounds which can be emitted by a synfuel facility it has been necessary to develop the concept of Risk Analysis Units (RAU's). Under this concept pollutants are grouped in broad, chemically-defined assessment categories that can be used for both environmental and health effects risk analysis. At present, 38 RAU's have been defined. For the hypothetical coal liquefaction plant, ORNL developed aquatic source terms for 17 RAU's, and atmosphere source terms for 25 RAU's. The models and methodologies sited above were then used to independently rank the RAU's with respect to environmental risk and, where possible, to quantify the risk estimates.

<u>SPECIFIC PEER REVIEW GROUP COMMENTS ARE:</u>

1. The ORNL work in environmental risk analysis is pioneering in many ways, and the general approach taken has provided a sensible structure to a previously unstructured area. However, substantial redirection of this work is required if it is to provide a useful understanding of synfuel impacts.

2. In any risk analysis, it is essential to carefully define the terms uncertainty and risk. This is essential although it is not apparent that it was done adequately in the ORNL study. In this regard, ORNL should reconsider its definition of risk and modify its orientation appropriately. ORNL's apparent preoccupation with uncertainty is both premature and ill-advised. The first step should be to develop measures of harm; the second to develop methods for estimating these measures; the third to obtain practical experience in implementing the methods, and finally to attempt to quantify the uncertainty in the estimation. From what was presented, it appears that the last step has preceeded the two previous steps. Additionally, objective approaches at quantifying uncertainty are usually not very successful. Generally there are major sources of uncertainty omitted from the analysis simply because they are difficult to quantify. For example, the EUA approach, as presented, focuses upon uncertainty analysis. Although, these types of models are attractive as analytical tools, in that they have built-in procedures for propagating uncertainty, one must express considerable reservation concerning our current ability to provide reasonable estimates of uncertainty to use as inputs. However, this does not necessarily mean that current efforts should be directed toward better determining the uncertainties. Rather, at this point, it would appear the effort could better be spent in

assuring that all significant risks are identified and in developing or improving estimates of the identified parameters.

It should be noted that the above comments should not be construed as downplaying the importance of uncertainty to the entire risk assessment process. A risk assessment is meaningless to a decision maker without some sense of the uncertainties involved in the analysis. In essence, a risk assessment must be viewed as a dynamic process in which the analysis and its credibility are improved with time as parametric uncertainties are identified and reduced through an ongoing research process.

3. The techniques that are utilized in the risk analysis appear to have been chosen primarily because of availability and apparent general appropriateness to environmental risk assessment. The selection criteria regarding the ability of the technique to address the issues and complexity inherent in the problem do not appear to have been adequately considered. Hence, procedures other than AHM, which explicitly address value judgements and professional judgements seem to be excluded (e.g. decision analysis, and social impact analysis etc.).
4. With regard to AHM, specific technical comments with respect to this process, as stated in the ORNL reports, are simply not correct. The Delphi Procedure is not a widely agreed upon procedure, nor does it necessarily lead to a consensus.

5. The radiological dose assessment was evidently used as the basis for estimating the steady-state transfer from soils to plants to animals. The original model is quite sophisticated as to consumption patterns, living patterns, specific food chains, climatic and precipitation variables, etc. - perhaps too sophisticated for application to chemical contaminants. A useful contribution has been made by ORNL in dividing the U.S. into regional "cells" for computational purposes, there are, however, some potentially serious problems in this approach in that important intra-regional differences may be ignored.

6. There was concern expressed about the lack of consideration of metabolism and metabolite formations. It was apparently assumed that inorganic molecules tracked the soil to plant transfer of organic compounds such as the PAH category. It is felt that the approach is highly provisional and is valid only to the extent that metabolic processes do not greatly change the parent compound or the relative potency of its metabolites. There has been enough work done on the unified theory of molecular carcinogenics to bring this whole concept into question. Any particular transfer coefficient could come under severe scientific criticism because it ignores metabolism, soil microbial, geochemical and other (e.g., photo-oxidant) transformations of the organic compounds. This approach may, in some cases, grossly over-estimate, or under-estimate, actual

concentrations in foodstuff for a given contamination event. Despite this concern, it was felt that the effort is worthwhile in that the approach has utility in giving a benchmark against which to evaluate actual data as they become available. In the absence of any real data, this may serve as a useful scaling function for some of the RAU's.

7. A common serious concern voiced by the Review Group as a whole was that involving the lack of testing or "validation" of the methods and models used. The Group felt that it was essential that experimental/field data be collected which will permit one to test the various methodologies available. The Group fully realized that acquiring such data will require considerable expenditures of cost and time, but is essential if environmental risk assessment is to become something more than just an interesting academic exercise. Typical of the Group comments provided was the following:

> "I would place highest priority on testing the methods that are being developed. We were shown comparisons of the results using the different analysis methods but never was a method applied to a "real" or simulated (microcosm) system and the results of such an application compared to observation. Without this step, scientific credibility is impossible."

HEALTH RISK ASSESSMENT

The health effects assessment of Synfuels under study of Brookhaven National Laboratory (BNL) is in its early stages. As such, it is difficult to comment extensively on the preliminary work in this area. No report was presented on the health exposure portion of this study. The health effect assessment was limited to carcinogenesis due to the RAU encompassing polycyclic aromatic hydrocarbons. Effects are estimated from exposures via air, surface water, terrestrial and aquatic food chains utilizing information supplied by ORNL. Dose-response functions for cancer are extrapolated from animal data. Cancer risk is calculated using the 1-hit, multi-hit, multi-stage, Probit, Logit, and Weibull models.

Specific Peer Group comments are:

1. As presented to date, the BNL work appears to be well thought out and sensibly organized. Given the present state of the art for assessing risks from low doses of potential carcinogens, they have defined an approach which delineates the uncertainty between cancer mechanisms (and models) and data limitations.
2. Considerable concern was expressed with regard to the credibility of dose-response relationships at low-dose levels (those that one might expect to find as a result of synfuel production). The extrapolation from high dose experimental data to low dose effects may constitute the major uncertainty in the health assessment for the foreseeable future.

3. Some of the predictions from the flexible models, such as Probit, are highly sensitive to very small changes in the data. One additional cancer can increase the estimate of risk, in some cases, by several orders of magnitude. Also, the Probit, Multi-hit, and Weibull models can produce estimates which make chemicals appear to be ultra-potent.
4. Data sets which contain only two dose levels are apparently omitted at present. These data sets should be included as their omission can cause bias.
5. The linear approximation used to estimate risk can cause large errors when the background level of a pollutant is small or non-existent.
6. The health effects assessment should work towards incorporating effects other than cancer (e.g., reproduction or respiratory effects) and towards making use of wider types of data. For example, consideration should be given to the use of data from short-term tests, including in vitro studies, skin painting, etc.

THE RISK ANALYSIS UNIT (RAU) CONCEPT

As stated earlier, the RAU concept was developed to permit a rational grouping of the myriad of chemical compounds potentially emitted from a synfuel site. As currently used in this program it provides common analysis categories for both the environmental and health effects assessments.

<u>SPECIFIC PEER REVIEW COMMENTS ARE:</u>

1. The RAU concept adopted by ORNL for exposure and environmental assessment and to a lesser degree by Brookhaven for health risk analysis seems to be a workable compromise between the over-whelming problem of dealing with a large number of chemicals on a case-by-case basis and the intractable problems associated with risk assessment of complex mixtures. The approach has limitations, e.g., the toxicity of an RAU category for one industry may be quite different than that of the same category for another industry, but these difficulties seem surmountable if rigid estimates of RAU toxicity are avoided. The rationale provided for use of RAU's was straightforward and reasonable, chemical categorization must be compatible with analytic methods, and categories should be mutually exclusive and collectively exhaustive.
2. One should identify clear criteria for selecting the risk analysis units (RAU). The approach, however, should be systematic in selecting the RAU's given not only what information is available, but more significantly, what information is desired from the analysis. For example, RAU's contain compounds that have significantly different effects on health and the environment. Since they are used for risk assessment should they not be categorized on the basis of health and environmental effects?

   With regard to RAU's for the purpose of Brookhaven National Laboratory, it might be useful to redefine certain groups in terms of a parameter such as relative toxicity. Issues raised about the widely varying toxicity of separate chemicals within an RAU might justify such a changed orientation. If the toxicity is known to vary widely, certainly the chemicals can be separately categorized.

3. RAU's for trace elements need to be "compound specific". Trace elements may have several oxidation states and be present as the oxide, chloride, etc. These different compounds will have different health and ecological effects and should be categorized as such.
4. RAU's for total stream matrices and possibly fractionated stream matrices (e.g., extractable organics - neutral/acid/base) can be defined based on experimental data.
5. Selection of the RAU's was probably based on existing sampling data. These data are, for the most part, taken inside process streams and do not reflect what compounds will be present in a synfuel plant's stream ultimately discharged to the environment. There are little or no data on treated effluents. These water treatment data do not represent an "integrated" plant effluent since other plant waste waters (e.g., raw waste treatment, filtration backwashes, sewer water, etc.) will be routed to the waste water treatment system. The RAU list can be prioritized based on what one would expect to reach the environment. However, fugitive emissions and worker exposure during routine maintenance should include all of the RAU's.

GENERAL COMMENTS

The following represent Peer Review Comments applicable to the entire EPA Synfuel Integrated Risk Assessment Program:

1. No treatment of occupational risk was discussed at the review meeting. Better integration of exposure data at pilot plants and industrial hygiene experience is needed to assess the occupational risk. Uncalibrated models are not likely to be useful for this effect.
2. Transient emissions may be the most environmentally significant problem associated with synfuels plants. Source estimates need to be made and in turn "spiked" ecological experiments performed to simulate these transient conditions.
3. A close review of the approach used to calculate plant emission sources is imperative. These data will drive the effects work. Since ORNL is directing this work, ORNL personnel need to thoroughly understand how the emission data are calculated, what data sources were used, how certainties are defined, etc.

   The results as applied to a real synfuels plant are questionable because representative emission source data had not been validated and therefore, not used. One of the conclusions reached was a prioritization of RAU's needing further work. This prioritization was based on equal emission rates for all RAU's. This will bias the model results and is not representative of a real life situation. The first step in prioritizing pollutants is to determine (or estimate) their presence and concentrations in discharge streams. Various technologies produce significantly different pollutants. The uncertainties of source emissions from different technologies need to be addressed. The characteristics of these discharge streams will also be different from plants using the same technology in that the selection of gas purification and pollution control systems will significantly affect the composition and flow of plant discharge streams.

4. Overall, the program is not, as yet, accomplishing the goal of effectively providing inputs to research needs. Very little was presented that would help decide where data need to be developed. Let us illustrate this using the health effect assessment. One would think that EPA would like to know where the gaps are in characterizing the health effects of RAU's. This probably could be accomplished by estimating what are likely to be the important RAU's, what are the important constituents of each RAU and what is known of each of these. This would give some idea of where data need to be generated through additional research. Similarly, one could list the major assumptions associated with using animal data to estimate human effects and decide what experiments might be helpful in improving this process.

   Similarly, in the case of the ecological risk assessment program, the outputs from the models presented would not be particularly helpful in guiding research. The AEE method outputs a number which reflects both toxicity and uncertainty. It is impossible to tell whether a high value results from a high level of toxicity or a high degree of uncertainty. Further development of this approach should be directed toward uncoupling these two aspects. It is believed to be feasible to present "best estimates" of the probability of harm and separate measures of the uncertainty in these estimates. The "best estimates" might be more useful to planners of control technology allocations whereas the uncertainty estimates might be useful in helping to guide research.

5. The RCRA risk-cost model which is also being developed by EPA has some features which might be worth considering for risk assessment for synfuels. The human health risk portion of the model considers many different types of human risks. The model develops "health risk scores" which can be applied to the components of a waste stream. These scores reflect the release rates, toxicity, persistence, and local conditions such as hydrology and population density. The scores are measures of harm to human health and can be converted, in a rough sense, to absolute estimates of numbers of cases. An approach similar to this might be considered for ecological assessment. That is, scores might be developed which are based upon a number of ecological parameters, and are felt to reflect environmental impairment. It might even be possible to use actual data from a real episode involving specific measured amounts of ecological impairment to calibrate the scores so that they truly represent risks of ecological harm. Such an approach could permit integration of a variety of data pertinent to ecological damage potential.

6. It is believed that this program should be viewed as a five-to ten-year effort to systematize the approach to integrated risk assessment. In view of the apparent uncertainties, the idea of having meaningful risk estimates in three years is unrealistic. Risk assessment must be viewed as a dynamic process that improves as delineated uncertainties and short-comings in the analytic process are reduced.

RECOMMENDATIONS

1. It is essential that a credible attempt be made to provide the data needed to test the environmental models proposed to be used. Such field experiments would include structural and functional measurements of algae or periphyton, aquatic invertebrates, and/or fish communities in a synfuel receiving system. However, an artificial stream microcosm, allowed to colonize with periphytes and seeded with selected insect populations, then dosed with increments of synfuel effluent, could be utilized as a substitute for the real world.
2. In general, the initial risk analysis program will not provide a scientifically credible evaluation of possible hazards unless the emission sources are well defined (or characterized). Also, transformation of species in the environment cannot be defined until the sources are characterized.

   Additional work needed to improve the credibility of the evaluation includes the following:

a. Development of process models/experiments to characterize the emission streams.

b. Development of a program to understand the effects mechanisms of the total stream matrix (e.g., how a "representative" effluent discharged to a receiving water body affects the stream/lake/river ecology).

c. Initiate work to identify the trace inorganic compounds present in the plants discharges.

If these cannot be done, then appropriate simplifying assumptions need to be made in the risk models. It is necessary to make sure that model and data accuracy are consistent.

3. Identification of carcinogens. By limiting consideration to chemicals found to be carcinogenic in animals and man, the possibility of false negatives is significant. Attention should be given to the distinction between those cases in which negative findings of carcinogenicity have been obtained from chemicals for which no experiments have been reported. A wider set of criteria for consideration of carcinogenicity should be developed. In particular we suggest the use of bioassay data.

4. Some attempt should be made to analytically discuss the implications of using all animal tumors as indicators, rather than only malignant tumors. How will this assumption affect human risk estimates?

5. Explicitly consider uptake and metabolism of major chemical hazards, and, if possible, base estimates on comparisons with animal data for

doses to target organs. The relevancy of animal experiments should include consideration of the exposure pathway; e.g., an animal inhalation study should not be given equal weight as an ingestion study when the human pathway is ingestion.

6. Endorsement of Delphi techniques and of the analytic hierarchy method is not justified, and no sensitivity to the difficulties and pitfalls of using subjective probability elicitation is indicated. Subjective methods may be needed in some instances, and subjectivity is inescapable in risk assessment. The group needs and should seek assistance if they plan to continue in this area in a formal way.
7. Examine the feasibility and desirability of providing subclassifications of RAU's based on adverse health and/or environmental effects.
8. Examine the possibility of reducing the toxicity data variability in the environmental models by using Bergman's data base rather than the Columbia River data base. This is predicated on the fact that since the Columbia River data were collected over the period from 1965 to 1978, it is doubtful that it used the acceptable protocols throughout. The Bergman toxicity data were generated using acceptable ASTM bioassay protocols.
9. In attempting to be constructive, this Peer review may give the false impression of being negatively critical. If this is the case, it is an entirely erroneous impression. The Group is highly supportive of the program, feels the researchers involved are quite competent in their

efforts to deal with a very difficult and complex area, and recommends strongly that the research continue to be supported by EPA. The promise of risk assessment offers one of the few available viable approaches for dealing, in a thoughtful manner, with the increasingly complex problems facing a society desirous of environmental protection. Efforts such as those provided by this program, as difficult as they may be, offer the primary mechanism for ultimately realizing that promise.

ATTACHMENT 1

PEER REVIEW GROUP MEMBERS
INTEGRATED HEALTH AND ENVIRONMENTAL RISK
ANALYSIS PROGRAM FOR SYNFUELS
ALEXANDRIA, VA
MARCH 28-29, 1983

CHAIRMAN

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ATTACHMENT 2

MATERIAL MADE AVAILABLE BEFORE PEER REVIEW MEETING

O'Neill, R. V., S. M. Bartell, R. H. Gardner, "Patterns of Toxicological Effects in Ecosystems: A Modeling Study, "Environmental Sciences Division, Oak Ridge National Laboratory, Oak Ridge, TN

Suter, G. W., D. S. Vaughan, and R. H. Gardner, "Risk Assessment by Analysis of Extrapolation Error: A Demonstration for Effects of Pollutants on Fish," Environmental Sciences Division, Oak Ridge National Laboratory, Oak Ridge, TN

Barnthouse, L. W., R. V. O'Neill, and G. W. Suter, "Environmental Risk Analysis," Environmental Sciences Division, Oak Ridge National Laboratory, Oak Ridge, TN

Barnthouse, L. W., D.L. DeAngelis, R. H. Gardner, et al (1982), "Methodology for Environmental Risk Analysis," Environmental Sciences Division, Oak Ridge National Laboratory, Oak Ridge, TN

Barnthouse, L. W., S. M. Bartell, D. L. DeAngelis, et al, "Preliminary Environmental Risk Analysis for Indirect Coal Liquefaction," Environmental Sciences Division, Oak Ridge National Laboratory, Oak Ridge, TN

Suter, G. W. and D. S. Vaughan, "Extrapolation of Ecotoxicity Data: Choosing Tests to Suit the Assessment," Environmental Sciences Division, Oak Ridge National Laboratory, Oak Ridge, TN

Suter, G. W., L. W. Barnthouse, and R. V. O'Neill, "The Uses of Uncertainty in Environmental Risk Analysis," Proceedings of the AAAS Symposium, Quantification of Risk: Reducing the Uncertainties, Santa Barbara, CA, June, 1982

Barnthouse, L. W., G. W. Suter, and R. V. O'Neill, "Ecological Risk Analysis: Definitions and Concepts," Environmental Sciences Division, Oak Ridge National Laboratory, Oak Ridge, TN

Barnthouse, L. W., S. M. Bartell, R. H. Gardner, et al, "Unit Release Risk Analysis for Environmental Contaminants of Potential Concern in Synthetic Fuels Technologies," Environmental Sciences Division, Oak Ridge National Laboratory, Oak Ridge, TN

A list of draft documents were furnished to Members of the Peer Review Panel prior to the Panel Meeting. These materials are contained in the Project Files.

MATERIAL MADE AVAILABLE DURING PEER REVIEW MEETING

Biesinger, K. E., H. L. Bergman, J. S. Meyer (1983), "Aquatic Ecosystem Effects of Process Waters Produced by Synthetic Fuel Technologies," Peer Review Meeting, EPA Integrated Health and Environmental Risk Analysis Program, March 29-30, 1983, Alexandria, Virginia

Morris, S. C., J. I. Barancik, H. Fischer, et al (1982), "Extrapolation to Health Risk: Use of Comparative Approaches," Proceedings of the Fifth Oak Ridge Life Sciences Symposium, October 24-27, 1982

Morris, S. C., H. C. Thode, Jr., J. I. Barancik, et al (1982), "Methods for Assessing Cancer Risks Using Animal and Human Data," U.S. Environmental Protection Agency, Washington, DC

University of Wyoming (1981), "Aquatic Ecosystem Effects of Process Waters Produced by Synthetic Fuel Technologies," 1981 Annual Report, University of Wyoming, Laramie, WY

University of Wyoming (1981), "Aquatic Ecosystem Effects of Process Waters Produced by Synthetic Fuel Technologies," Department of Zoology and Physiology, University of Wyoming, Laramie, WY

University of Wyoming, "Publications, Reports and Presentations, 1977-1982," Department of Zoology and Physiology, University of Wyoming, Laramie, WY

U.S. Environmental Protection Agency (1981), "Complex Effluents Toxicity Information System Description and Status", Environmental Research Laboratory, U.S. Environmental Protection Agency, Duluth, MN

A list of draft documents were furnished to Members of the Peer Review Panel prior to the Panel Meeting. These materials are contained in the Project Files.

ATTACHMENT 3

AGENDA FOR THE
PEER REVIEW PANEL ON THE INTEGRATED
HEALTH AND ENVIRONMENTAL RISK ANALYSIS PROGRAM FOR SYNFUELS

ALEXANDRIA, VA

MARCH 29, 1983

1:00	Introduction	Dr. Norman R. Glass
1:15	Background Information on Synfuels Health and Environmental Risk Analysis	Dr. A. Alan Moghissi
1:45	Environmental Risk Analysis Program	Dr. Carl Gehrs, et al.
5:00	Questions to Program Presenters	Peer Review Panelists

MARCH 30, 1983

8:00	Exposure of Humans to Synfuels Chemicals through the Food Chain	Dr. Jerry Eisele
9:00	Exposure of Humans to Synfuels	Dr. Marilyn Miller, et al.
9:30	Health Risk Analysis Program	Dr. L. D. Hamilton
12:00	Lunch	
1:00	Questions to Program Presenters and writing Draft Report	Peer Review Panelists
5:00	Meet with EPA Program Managers	Peer Reviewers

ATTACHMENT 4

PARTICIPANTS
INTEGRATED HEALTH AND ENVIRONMENTAL RISK ANALYSIS PROGRAM FOR SYNFUELS
ALEXANDRIA, VA
MARCH 28-29, 1983

Dr. Roy Albert, New York University Medical Center

Dr. Fred Baes, Oak Ridge National Laboratory

Dr. Jerome Barancik, Brookhaven National Laboratory

Dr. Larry Barnthouse, Oak Ridge National Laboratory

Dr. Steve Bartell, Oak Ridge National Laboratory

Dr. Harold Bergman, University of Wyoming

Dr. Melvin W. Carter, Georgia Institute of Technology

Dr. Don S. Cherry, Virginia Polytechnic Institute and State University

Dr. Kenneth Crump, Science Research Systems, Inc.

Dr. Jerry Eisele, Oak Ridge Associated Universities

Dr. Albert Galli, Environmental Protection Agency

Dr. Carl Gehrs, Oak Ridge National Laboratory

Dr. Norman R. Glass, Corvallis Environmental Research Laboratory

Dr. Stanley M. Greenfield, Systems Applications, Inc.

Dr. L. D. Hamilton, Brookhaven National Laboratory

Dr. Steve Hildebrand, Oak Ridge National Laboratory

Dr. George Innis, Colorado State University

Dr. Ralph Kenney, Woodward-Clyde

Dr. A. Alan Moghissi, Environmental Protection Agency

Dr. Sam Morris, Brookhaven National Laboratory

Dr. Gordon Page, RADIAN

Dr. Don Rodier, Environmental Protection Agency

Dr. Glen W. Suter, Oak Ridge National Laboratory

Dr. Henry Thode, Brookhaven National Laboratory

Dr. Burton Vaughan, Battelle Pacific NW Laboratory

Dr. David Weber, Environmental Protection Agency

Dr. Chris Whipple, Electric Power Research Institute

REPORT OF THE

PEER REVIEW PANEL

ON THE FOOD CHAIN TRANSPORT OF SYNFUELS

FOR THE

U.S. ENVIRONMENTAL PROTECTION AGENCY

INTEGRATED HEALTH AND ENVIRONMENTAL RISK ANALYSIS

PROGRAM FOR SYNFUELS

MEETING HELD AT

CORVALLIS, OREGON

OCTOBER 27-28, 1983

REPORT DATE

NOVEMBER, 1983

REPORT OF THE PEER REVIEW PANEL ON THE FOOD CHAIN TRANSPORT OF SYNFUELS

PURPOSE

The purpose of this report is to summarize the results of a peer review of the U.S. Environmental Protection Agency's research effort in the area of Food Chain Transport of Synfuels. The review was conducted October 27-28, 1983 at the Environmental Research Laboratory - Corvallis in Corvallis, Oregon by a special Peer Review Panel established for this purpose. Members of the Peer Review Panel are identified in Attachment 1.

Research ongoing in animal uptake of synfuels chemicals at the Oak Ridge Associated Universities in Oak Ridge, TN and research underway at the Environmental Research Laboratory in plant uptake of synfuels chemicals in Corvallis, OR were reviewed. These programs are those supported by the Integrated Health and Environmental Risk Analysis Program for Synfuels of the U.S. Environmental Protection Agency.

PROCEDURE

Members of the Peer Review Panel were provided with various reports which relate directly to the research under review. These materials are listed in Attachment 2.

The meeting agenda is given in Attachment 3. The participants included the Principal Investigators for the animal and plant research, Dr. G. R. Eisele and Dr. J. C. McFarlane, respectively and members of their staffs. Dr. Shan-Ching Tsai, a chemist on Dr. Eisele's staff, also made a formal presentation to the Peer Review Panel and several members of the Corvallis Laboratory group made comments during the course of the review.

Dr. A. Alan Moghissi was a meeting participant as was Dr. Fred Baes of the Environmental Sciences Division of the Oak Ridge National Laboratory. Dr. Moghissi is the Project Officer of these research activities whereas Dr. Baes is involved with the modeling of the food chain for synfuels.

COMMENTARY

ANIMAL STUDIES - GENERAL COMMENTS

There was general satisfaction in the overall progress of Dr. Eisele's group on the food chain transport of synfuels in food producing animals (dairy cattle, swine and poultry). He has incorporated the important comments from the previous peer review panel (May, 1982) into the experimental protocols. For example, concentrations of parent compound and total metabolites in the various treatment groups are now quantified. The consensus opinion of the Peer Review Panel was that further characterization and measurement of individual metabolites would not be an effective utilization of resources. Although such information would be of academic interest, it would not increase the precision of risk analysis enough to warrant the large expenditure of resources required to obtain complete metabolic profiles for each chemical tested. However, the Panel did feel that in limited cases, quantification of metabolites that are known to be intimately involved in the mechanism of action would produce useful information in the risk analysis process provided that appropriate standards are available.

The Peer Review Panel felt that Dr. Eisele is well qualified to conduct the studies of food chain transport of synfuels in food producing animals as he has been conducting similar studies for a number of years and possesses a clear understanding of the problems involved in generating valid uptake and retention data for chemicals in large animals. An essential component in these studies is collaboration with a skilled chemist and the Panel noted that Dr. Tsai possesses the expertise required to identify and quantify the chemicals indicated in the RAU list. The Peer Review Panel agreed that the experimental protocols are providing appropriate information needed to produce valid risk analysis models. Several points were raised by Panel members regarding optimization of the protocols that would increase the utility of the data without increasing costs. These are as follows:

ANIMAL STUDIES - ITEMS IDENTIFIED FOR CONSIDERATION

Because the cost of animal experimentation is high, it is important to optimize the experimental design to generate as much useful information per test as possible. A good estimate of the rate of clearance of the chemical is especially important. Therefore, it would be beneficial to include one additional sampling time for the clearance phase of the acute exposures - at least for poultry and swine. A possible sampling sequence would be 1, 3, and 5 days after exposure. Although this would require the use of additional animals, it would improve the estimate of clearance rate constants considerably. The clearance rate constant may then be used to optimize the design of the 30-day chronic test, since time-to-steady-state is a direct function of clearance rate constant. If clearance is slow, then it takes a relatively long time to reach steady-state and many of the samples taken during the uptake phase of the 30-day chronic can be eliminated. If clearance is rapid, then steady-state may be established soon after the beginning of the chronic exposure. Effort saved by reducing the number of samples during uptake should be switched to more samples during steady-state and clearance phases.

It is recommended that animals in both the acute and chronic tests be pre-dosed with unlabeled chemical for one week minimum prior to administration of the labeled material. That practice should eliminate irreproducibility caused by enzyme induction or other subtle effects.

For the same reason, it would be helpful to standardize the dose of test chemicals given to each of the three species on a gram/kg body weight basis.

The tissues that have been selected for analysis are quite appropriate. An examination of the existing information on residue levels is milk fat vs. body fat of cows should show a reasonable correlation. If so, such a correlation could be used to estimate changes in body fat residues during both uptake and clearance. It is recommended that blood be collected and analyzed at the time of sacrifice and at any other times that are reasonable, so that correlations between the important blood compartment and other tissues can be made, again for predictive purposes.

Perhaps an efficient alternative approach to the present strategy of testing one chemical thoroughly in all three species is to spend proportionately more effort testing a wide variety of chemicals in one of the species (poultry or rat). Better correlations between residue levels in fact and edible tissues could be made on that species. Only the chemicals with high bioaccumulation factors would then be retested in the expensive large animals such as the cow. A greater reliance on species to species correlations might be profitable in the long run.

PLANT STUDIES - GENERAL COMMENTS

The Panel was favorably impressed by the plant uptake portion of the study and it felt that the overall design, particularly the whole plant uptake test, is very sophisticated and well designed. The Panel was particularly impressed with the degree to which the experimental parameters (temperature, air movement, CO_2, nutrient solution circulation, etc.) are controlled and monitored. The initial results on uptake confirm the feasibility of the approach and suggest that there is a relationship between uptake rate and transpiration rate. It is felt that the quantitation of this relationship and the demonstration of its general applicability to a variety of plant species and different zenobiotic chemicals would be a very important basic contribution to the problem of applying structure-activity data to food chain modeling.

The system using whole plants has a capacity to rapidly produce a large data base, but it was not obvious to the Peer Review Panel how the results would be used with confidence in food chain modeling without incorporating soil-water-zenobiotic interactions. Obviously, results from the system using root tips to measure uptake will have to be considered suspect for use in the food chain model until correlated and "validated" against whole plant data. In this context, it is also important to stress the need to establish retention index values for parent compounds.

PLANT STUDIES - ITEMS IDENTIFIED FOR CONSIDERATION

The Panel was concerned that the hazard assessment was not addressing a very important part of the food chain transport, namely foliar exposure or contamination. It felt that direct exposure to plants of aerially transported chemicals will, in the initial development of the synfuels industry, be very important. Since aerial transport is apparently not being addressed at the present time, the Peer Review Panel feels that the plant work (i.e. plant uptake via hydroponics vs. foliar exposure) be re-evaluated by the Project Officer.

The Panel felt that only part of the goal, to determine the extent of chemical uptake by plants, will be achieved by the hydroponic experiments. It feels that the ability to actually measure uptake (from the root to plant tops) is very well designed. The investigators have an excellent design and can control all of the important parameters. However, the investigators are making the assumption that the chemical will be biologically available to the plant root. The Panel feels that bioavailability and persistence of the chemical in soil must be considered in order for the plant uptake data to be useful. Obviously, if a chemical will never reach the root zone in an amount or form that can be taken up by the plant, then the uptake data will be of little value to the concept of food chain transfer. The environmental fate of a chemical in soil needs to be considered in order to determine if a chemical will be available for plant uptake. For example, some of the chemicals being studied degrade so rapidly in soil that their presence in significant levels in real world environmental situations seems unlikely. All of the many factors that influence environmental fate, such as degradation rate, adsorption, microbial population, leaching, soil properties, etc. must be considered.

The hydroponic experiments are very well designed and few additional considerations are needed. However, the Panel feels the investigators should evaluate the clearance rates of the various chemicals from the plant tissue. Analysis of the plant for parent compound and metabolites with time will indicate if a chemical is accumulating or if it is being lost or degraded.

Unless there are sound reasons for doing otherwise, the selection of chemicals for plant uptake work should be the same as that used in the animal studies. Also, published regressions are available relating soil binding of chemicals to their water solubility or partition coefficient. These should be considered to estimate the availability of the test chemicals to the plants.

ATTACHMENT 1

MEMBERS OF THE PEER REVIEW PANEL
CORVALLIS, WA
OCTOBER 27-28, 1983

CHAIRMAN	Dr. Melvin W. Carter Nuclear Engineering and Health Physics Georgia Institute of Technology Atlanta, Georgia 30332
	Dr. A. S. W. DeFreitas Atlantic Research Laboratory National Research Council of Canada 1411 Oxford Street Halifax, Nova Scotia B3H 321 Canada
	Dr. Allan Isensee Pesticide Degradation Laboratory Agricultural Environmental Quality Institute Department of Agriculture, Building 050 Beltsville Agriculture Research Center Beltsville, Maryland 20705
	Dr. George Lucier Receptor Pharmacology Section National Institute of Environmental Health Sciences Department of Health and Human Sciences P. O. Box 12233 Research Triangle Park, NC 27709
	Dr. Anne Spacie Department of Forrestry & Natural Resources Purdue University West Lafayette, Indiana 47907

ATTACHMENT 2

1. "Food Chain Transport of Synfuels", G. R. Eisele, Report Prepared for Peer Review Panel, 26 pages.

2. "Food - Chain Transport of Synfuels", G. R. Eisele, T. D. Traylor, O. J. Schwarz, and R. J. Chertok, Annual Report, January 17, 1983, 44 pages.

3. "Solvent Extraction and HPLC Analysis of Aniline and Its Metabolites in Animal Tissues", Shan-Ching Tsai and Gerhard R. Eisele, October, 1983, 12 pages.

4. "The Use of Roots Excised from Barley to Understand Absorption of Chemical Elements and Compounds by Plants", Carlos Wickliff, Inhouse Report, June, 1983, 17 pages.

5. "Chemical Fate in Terrestrial Plants - A Research Plan", Craig McFarlane, Hilman Ratsch, and Carlos Wickliff, 19 pages.

6. "Uptake of Bromacil by Isolated Barley Roots", Carlos Wickliff, J. C. McFarlane, and Hilman Ratsch, accepted for publication in Environmental Monitoring and Assessment, April, 1983, 19 pages.

7. "Uptake of Bromacil, Phenol, and Formaldehyde by Excised Barley Roots", Carlos Wickliff, J. C. McFarlane, and Hilman Ratsch, Inhouse Report, October, 1983, 20 pages.

8. "Isolated Root Uptake Test (IRUT) Verification Proposal", 16 pages.

List of Reference Materials furnished to the Members of the Peer Review Panel. These materials are contained in the Project Files.

ATTACHMENT 3

AGENDA
PEER REVIEW PANEL MEETING
FOOD CHAIN RESEARCH ON SYNFUELS CHEMICALS
CORVALLIS, OR

OCTOBER 27, 1983

8:00	Welcome	Tom Murphy, CERL Director
8:30	Outline of Research Program and Charge to Panel	Alan Moghissi
9:00	Food Chain Studies with Synfuels Chemicals	Jerry Eisele
12:00	Lunch	
1:30	Food Chain Studies with Synfuels Chemicals	Craig McFarlane
4:30	Recess	

OCTOBER 28, 1983

8:00	Tour Plant Research Area
9:00	Question and Discussion Session with Researchers
12:00	Lunch
1:00	Peer Review Panel for Evaluation and Report Preparation
4:30	Conclusion

REPORT OF THE
PEER REVIEW PANEL
ON HEALTH EFFECTS OF EXPOSURE IN A
COAL GASIFICATION PLANT

FOR THE

U.S. ENVIRONMENTAL PROTECTION AGENCY

INTEGRATED HEALTH AND ENVIRONMENTAL RISK ANALYSIS

PROGRAM FOR SYNFUELS

MEETING HELD AT

BROOKHAVEN NATIONAL LABORATORY

UPTON, NEW YORK

NOVEMBER 9, 1984

REPORT DATE

NOVEMBER, 1984

REPORT OF THE PEER REVIEW PANEL ON HEALTH EFFECTS OF EXPOSURE IN A COAL GASIFICATION PLANT

PURPOSE

The purpose of this report is to summarize the results of a peer review of the "Health Effects of Exposure in a Coal Gasification Plant" which is operated in Kosovo, Yugoslavia. The research is an inherent part of the U.S. Environmental Protection Agency program titled "Integrated Health and Environmental Risk Analysis Program for Synfuels". The peer review was conducted at the Brookhaven National Laboratory on November 9, 1984 by a special Peer Review Panel convened for this purpose. Membership of the Peer Review Panel is indicated in Attachment 1.

PROCEDURE

Prior to the November 9th meeting, members of the Peer Review Panel were furnished copies of the following documents for review:

"Occupational Health Study of the Electroprivreda Kosovo Coal Gasification Plant at Pristina, Yugoslavia; The Industrial Hygiene Program". Draft report of October 7, 1983.

"Protocol for the Detailed Characterization Campaign of July, 1984 at the Electroprivreda Kosovo Coal Gasification Plant, Pristina, Yugoslavia". Draft report of May, 1984.

"Kosovo Gasification Plant Study: Retrospective Epidemiological Phase" - October 15, 1984.

These documents were distributed by Sam Morris.

The tentative agenda is shown as Attachment 2 and a list of speakers is presented as Attachment 3. Various other individuals from Brookhaven

National Laboratory and from Yugoslavia attended the meeting and participated in certain parts of the discussion.

Our commentary and recommendations are based on the briefings and discussion which occurred on November 9 as well as review of the several documents furnished to the Panel Members. The format for this is a reflection of responses to several questions posed to the Panel by the Project Officer, from the U.S. Environmental Protection Agency.

COMMENTARY AND RECOMMENDATIONS

1. Is the design and conduct of industrial hygiene study likely to produce results applicable to the U.S. synfuel industry?

The study of exposures appears to be a well-designed effort which has the potential to produce results applicable to the U.S. synfuel industry. A serious question arises, however, in whether the problems which have become apparent in the conduct of the three characterization campaigns done to this point will prevent the study from ever reaching its objectives. Specifically, it seems that the purposes and objectives of the detailed characterization campaigns have been only partially fulfilled. The most serious deficiency of the data collected to this point is the limited amount of information presented on the variety (i.e. composition) and levels of PAH exposures. The difficulty of successfully conducting sampling and analysis for personal exposures to these compounds is not under estimated; however, it must be accomplished if the purposes of the industrial hygiene and exposure assessment are to be met. At this point, it appears that the investigators do not yet have sufficient information in hand to proceed with Tasks 2 to 5 identified in the industrial hygiene and exposure assessment protocol.

In considering the applicability of these efforts to the U.S. synfuels industry, it must be recognized that the Yugoslavian facility offers a unique workshop in which many of these extremely difficult problems in exposure characterization may be addressed. A preliminary conclusion is that the study is likely to produce applicable results, provided the problems with the detailed characterization of the plant atmosphere can be solved. To this end, it seems that the task identified as technology transfer should be elevated to a very high priority, so that more detailed characterization studies can be conducted earlier in the research program.

2. **Is the design and conduct of industrial hygiene study likely to produce results useful for the conduct of epidemiological studies?**

Observations on the industrial hygiene study to this point, made in response to Question 1, apply to the issue of the epidemiological studies as well. Given the extra ordinarily complex and variable nature of the exposures in the gasification process, it seems that the best approach would be to conduct as much sampling and analysis as is necessary to:

a. provide a detailed characterization of the composition and level of exposure, and

b. allow the selection of a meaningful index of exposure which could be monitored extensively.

It is clear to all parties associated with the study that detailed analysis of personal exposures is not feasible on an extended basis, but it is equally apparent that some measure of average exposure and variability of exposure must be developed. The preliminary conclusion is that the design of the industrial hygiene study will allow a properly conducted study to produce results useful to the epidemiological studies; in fact, it may be that the success of the epidemiological study is predicated upon the development of accurate exposure classifications. Whereas the exposure characterizations conducted to this point represent a very significant effort, they are not yet sufficiently developed to be useful in an epidemiological study. As previously stated, it may be that acceleration of the technology transfer task will resolve this problem.

3. **Is the design and conduct of the retrospective epidemiologic study likely to produce meaningful results?**

In spite of the small numbers in some job categories and the limited number of workers overall, as well as the complexity of environmental exposures, the proposed study is definitely worth undertaking. The opportunity of studying possible adverse health effects in workers exposed for more than 10 years in an operating, full-scale gasification complex is unique.

Several factors should promote a successful outcome of the studies: these include a stable work force, with much less turnover, change from one job category to another and change of residence, as compared to the U.S.; a well developed standardized medical service and record system, involving both gasification plant workers and lignite miners; effective working relationships with the Pension Fund and provincial health department; the likelihood that reasonably sound exposure information will be available; and finally, that effective working relationships have already been established between key Yugoslavia and U.S. scientists.

In addition, the investigators responsible for the epidemiologic aspects and the environmental exposure estimates are fully aware of the difficulties and complexities of this kind of study. There are many potential hazards to workers and most of these have shown large variability with time and place; this will limit the definition of specific chemical exposures. There are also physical factors, such as noise and excess heat, to be taken into account in addition to chemical exposures.

In spite of the stability of workers mentioned above, the total number of workers (approximately 750) is very small for many epidemiologic purposes. When broken down by job rubrics, the numbers become very small. The resulting lack of statistical power seems apparent to the investigators.

4. **Is the design and conduct of the prospective study likely to produce meaningful results?**

This question is difficult to answer without qualification. If results of the retrospective study are utilized in planning a definitive prospective study, it is likely that all workers should be studied for a number of years with selected standardized tests. Presumably, it would be understood that the kinds and levels of exposure would not change significantly in the future. However, there are two trends working against this possible future. One is the possibility of retrofitting control systems, which would reduce exposures, and which is apparently being planned. Secondly, the technology transfer program now being implemented should also reduce the amount of exposure. Obviously this would be in the best interest of the workers, but it would change the assumptions of a prospective study.

The project plans do not make a clear distinction between the protocol for a typical prospective study and the intensive clinical and laboratory studies being considered for special groups of workers (detailed pulmonary function analysis, cytogenetics and "molecular epidemiologic" studies, for example). Many of the latter are in research or developmental phases, and it is not clear how many of these tests would be useful in the Kosovo studies (that is, would provide information that could not be obtained less expensively with well standardized tests). Nevertheless, such specialized tests used on a pilot basis could give valuable information when applied to limited numbers of workers who are well characterized in terms of their individual exposure histories and in terms of symptomatology and other evidence of potential adverse health effect.

These uncertainties, concerning both the general levels of exposure and the possibility of accurate characterization of exposure of individuals, must be taken into account in the further planning of any prospective or clinical studies.

5. **Is the overall scientific quality of the study sufficient to justify its support?**

The workers of the Kosovo gasification plant represent a unique study population in terms of the intensity and duration of their occupational exposure. Although the level of their exposure may represent a "worst case" situation in comparison with the levels that are likely to be encountered in U.S. plant, the Kosovo workers constitute a sentinel population worth studying in assessing the potential occupational health impacts associated generically with the gasification process. The scientific quality of the present study is inevitably limited by the size of the study population, which is not large enough to detect small increases in morbidity or mortality. In addition, the adequacy of the statistical design and the appropriateness of the control population remains to be established. Nevertheless, Dr. Haxhiu is an accomplished clinical investigator and can be expected to exploit effectively the collaborative assistance of his U.S. colleagues. It is evident that the collaboration is developing productively and that further joint effort will enable study of the Kosovo workers to be placed on a sound footing. The stability of the Kosovo worker population and the quality of their health record systems constitute especially favorable resources.

In summary, the overall scientific quality of the study is sufficient to justify its continued support at a level that enables the Yugoslavian scientists to gain the analytical competence necessary to assure its successful completion.

ATTACHMENT 1

PEER REVIEW PANEL MEMBERS
HEALTH EFFECTS OF EXPOSURE IN A COAL GASIFICATION PLANT
UPTON, NEW YORK
NOVEMBER 9, 1984

CHAIRMAN

Arthur C. Upton, M.D.
Department of Environmental Medicine
New York University Medical Center
550 First Avenue
New York, New York 10016

Dr. Melvin W. Carter
School of Nuclear Engineering and Health Physics
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Atlanta, Georgia 30332

Mr. Robert F. Herrick
Industrial Hygiene Section
National Institute of Occupational Safety & Health
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James L. Whittenberger, M.D.
Southern Occupational Health Center
University of California
19722 McArthur Boulevard
Irvine, California 92717

ATTACHMENT 2

AGENDA
PEER REVIEW PANEL MEETING
HEALTH EFFECTS OF EXPOSURE IN A COAL GASIFICATION PLANT
BROOKHAVEN NATIONAL LABORATORY
UPTON, NEW YORK

NOVEMBER 9, 1984

9:00	Welcome	Richard Setlow
9:10	Overview	Robert Goldsmith, DOE Alan Moghissi, EPA Musa Haxhiu, Yugoslavia
10:30	Industrial Hygiene and Exposure Assessment	Otto White, BNL
12:00	Lunch	
1:00	Retrospective Epidemiology	Sam Morris, BNL
2:30	Prospective Epidemiology	Maria Pavlova, BNL
3:30	Executive Session	Peer Review Panel
5:30	Adjourn	

ATTACHMENT 3

LIST OF SPEAKERS
PEER REVIEW PANEL MEETING
HEALTH EFFECTS OF EXPOSURE IN A COAL GASIFICATION PLANT
BROOKHAVEN NATIONAL LABORATORY
NOVEMBER 9, 1984

Richard Setlow, Brookhaven National Laboratory

Robert Goldsmith, DOE Project Officer

Alan Moghissi, EPA Project Officer

Musa Haxhiu, Government of Yugoslavia and Project Officer

Otto White, Brookhaven National Laboratory

Jim Jackson, Los Alamos National Laboratory

S. Kapor, INEP

Eugene Premuzic, Brookhaven National Laboratory

Sam Morris, Brookhaven National Laboratory

Maria Pavlova, Brookhaven National Laboratory

Robin Perera, Columbia University

Robin Leonard, Brookhaven National Laboratory

Randy Brill, Brookhaven National Laboratory

Herb Suskin, Brookhaven National Laboratory

E-25-K01

Georgia Institute of Technology

A UNIT OF THE UNIVERSITY SYSTEM OF GEORGIA
SCHOOL OF MECHANICAL ENGINEERING

May 7, 1986

Please reply to:

NUCLEAR ENGINEERING AND
HEALTH PHYSICS PROGRAM
CHERRY EMERSON BUILDING
GEORGIA INST. OF TECH.
ATLANTA, GEORGIA 30332 U.S.A.

MEMORANDUM

TO: OCA/PPC

FROM: Melvin W. Carter

SUBJECT: DRAFT REPORT - PROJECT #E25-K01

This Draft Report was sent to the Project Officer and to technical reviewers throughout the United States for critical review. Comments have been and are being received and will be carefully considered in preparing a second draft of the report.

As requested, two copies of the Draft Report are enclosed.

Melvin W. Carter

MWC/bc
Enclosures

(DSR)

Georgia Institute of Technology

A UNIT OF THE UNIVERSITY SYSTEM OF GEORGIA

SCHOOL OF MECHANICAL ENGINEERING

March 24, 1986

Please reply to:

NUCLEAR ENGINEERING AND HEALTH PHYSICS PROGRAM
CHERRY EMERSON BUILDING
GEORGIA INST. OF TECH.
ATLANTA, GEORGIA 30332 U.S.A.

Dr. Kenneth Hood
U.S. Environmental Protection Agency
401 M. Street, S.W., Room 381C
Washington, D.C. 20460

Dear Ken:

Thank you for making relevant reports and references available regarding your research activities related to the EPA's "Integrated Health and Environmental Risk Analysis Program for Synfuels". These have been most useful in our efforts to prepare a summary report of these past research contributions to the total effort.

A rough draft of this summary report is nearing completion and will follow the outline which is enclosed. However, we have drafted a number of individual sections and these are available for technical review.

I very much appreciate your willingness to critically review those parts pertinent to your research program. These parts are enclosed for this purpose.

I'm especially interested in your comments and suggestions for improvement as these reflect the important research contributions made by you and your colleagues. Obviously, we need update material and proper attributions (references) to reports, papers, talks, and other literature citations.

Your identification of major and minor conclusions reached during your work as well as pertinent recommendations would be particularly useful. These, on a consolidated basis, will be carefully considered in the drafting of these particular sections of the summary report.

We also anticipate having a procedural step to accommodate a scientific review of the total draft report subsequent to its completion. Your help in this part of the process would also be most desirable.

Please send your comments and suggestions to my by April 15, 1986. This time frame will allow full consideration and utilization of the various contributions which should be received.

Your interest and assistance are very much appreciated.

Best personal regards.

Sincerely yours,

Melvin W. Carter
Neely Professor

MWC/bc
Enclosures

DRAFT

INTEGRATED HEALTH AND ENVIRONMENTAL RISK ANALYSIS PROGRAM FOR SYNFUELS

I. Introduction

II. Energy Technologies to Produce Synfuels

Coal Gasification

Indirect Coal Liquefaction

Direct Coal Liquefaction

Oil Shale

Tar Sands

III. Assessments of Synfuel Technologies

IV. Occupational Assessment

Exposure Assessment

Epidemiology

Medical Evaluation of Workers

Coke Oven Workers

Kosova

V. Environmental Assessment

Food Chain

Terrestrial - Animals and Plants

Aquatic

VI. Health Assessment

Mutagenic

Reproductive

Carcenogenicity

Inhalation Toxicology

VII. Integrated Environmental Risk Assessment

VIII. Integrated Health Risk Assessment

IX. User's Review Meetings

X. Workshops

XI. Peer Review

XII. Conclusions

XIII. Recommendations

XIV. Summary

APPENDIX 1

Appendix 1

Will Include The Final Reports

of the

Peer Review Groups and Panel.

I. INTRODUCTION

Synthetic fuels are usually considered to include gaseous and liquid fuels as well as solid fuels which have been produced from the conversion of coal, oil shale, tar sands, and various forms of biomass. The conversion processes may be defined as synfuels technologies and there are a number of these.

Among the reasons for using synfuels technologies are: the removal or conversion of nitrogen, sulfur, and other components which give rise to undesirable pollutants; the utilization of inherent energy resources and thus, the achievement of independence from foreign sources; the replacement of unavailable, depleted, or more costly supplies of natural fuels; and the production of higher calorific fuels by the removal of unwanted constituents such as ash which makes for economies in fuel handling and transport.

Some of the impetus in the United States was generated by the oil embargo of a few years ago and by a continuing increase in the costs of finding and producing new fossil and other energy sources. It is also widely recognized that the world's supply of readily producible oil and natural gas is limited and will be exhausted in a relatively short period of time.

Concurrently, the realization has come that with increased demands for energy it is prudent to secure alternative sources of energy along with the technologies necessary for their production and utilization. We have also learned that energy conservation methods, while helpful, are not sufficient to achieve our goals.

In addition, a number of newer energy production technologies, such as solar and fusion, are extremely long-range efforts with the outcome as to production an uncertain occurrence.

Thus, for the decades immediately ahead it appears that beyond our sources of natural gas and oil we shall be dependent primarily on coal, uranium, and perhaps oil shale.

During our recent decade of prime concern with energy sources has been the fundamental interest and perception of the desire and need for basic environmental quality. This era began in the late sixties and emerged in 1970 with the creation of the U.S. Environmental Protection Agency and the Environmental Quality Council. The intense national mood and interest were codified in the passage of the National Environmental Policy Act of 1969.(REF) Ref

Consequently, there has been a merging of these two national concerns; namely the need to develop and produce alternate long-term energy sources and to make the technologies and fuel utilization processes as benign and innocuous to the public and its environment as possible. Thus, the constituencies and advocates for these two major national objectives are not necessarily mutually exclusive although they may not be completely compatible in all respects.

To some extent, the Energy Security Act of June 30, 1980 (REF) embodied each of these concerns. The Act created the U.S. Synthetic Fuels Corporation (SFC), defined its purpose, organization, financing, and responsibilities as well as the environmental and health protection and monitoring requirements of each recipient of financial assistance from the SFC, and set production goals for industrial output of synthetic fuels. Ref

Of particular interest here, in addition to the industrial stimulus it provided, are the definition of "synthetic fuels" and the requirements for environmental and health protection.

According to the Energy Security Act, synthetic fuels are any solid, liquid, or gas produced from coal (including lignite and peat), shale, tar sands, certain categories of heavy oil, water for its hydrogen content, coal-oil mixtures, and magneto hydrodynamic topping cycles.

It also describes the major environmental and health protection and monitoring provisions to include that the supported projects must: be consistent with protection on the environment and environmentally acceptable; have a high potential to meet regulatory requirements; and present a plan for monitoring environmental- and health-related emissions.

Even Congressional Committees such as the House Committee on Science and Technology and its Subcommittee on Energy Research and Production have expressed the view that environmental, health, and safety research is the key to the prospects for developing and building environmentally acceptable synthetic fuel plants. These Committees, of course, are supply oriented with emphases on national security, energy, and technology rather than on environment, health, safety and protection.

Individuals with industry, such as G.K. Vick of Exxon Research and Engineering Company(REF), have also stated their views regarding the need for safety and protection as an inherent part of industrial synfuels technology development. The developed technologies need to be safe to workers, customers, environment, and the general public. Of course, they need to be acceptable to the customers and the public. Ref

The U.S. Environmental Protection Agency took steps on a timely basis to put in to place a comprehensive program of research and development to produce needed information and data for the development of regulatory standards for synfuels technologies and the use of their products. Thus, different from many industrial developments, the environmental and health protection programs are being developed on a concurrent basis with synfuels technologies.

A major component in the Environmental Protection Agency effort was the establishment of a Program titled Integrated Health and Environmental Risk Analysis Program for Synfuels. It was set up under the aegis of the Office of Research and Development.

II. ENERGY TECHNOLOGIES TO PRODUCE SYNFUELS

Contrary to popular belief, the production of synthetic fuels to help meet energy requirements has been obtained in a number of countries. This, of course, is not the case in the United States as there has been little emphasis placed on the need to develop synfuel technologies.

In this section we shall briefly review synfuels technologies and the possible production of synfuels for use. Needless to say, the establishment of the SFC added emphasis to these efforts within the U.S.

The basis for synfuels technologies is the conversion of carbonaceous materials to synthetic fuels through the process of hydrogenation. Thus, our common fuels such as natural gas and gasoline have a higher hydrogen content than the raw materials considered as resources for conversion. These include coal, oil shale, tar sands, and several forms of biomass.

In the hydrogenation processes the source of hydrogen which is added is water. Therefore, the synfuel technologies are intended to decrease the carbon to hydrogen ratio in the conversion process. For example, on a mass basis the ratio of carbon to hydrogen varies from about 15 for bituminous coal, approximately 9 for crude oil, to 6 and 3, respectively, for gasoline and methane. Oil shale and tar sands are close to crude oil in carbon to hydrogen ratio and are thus more amenable to synfuel technology than coal.

Another concern is the amount of mineral material contained in the energy resource. If the content is high, large quantities of material must be mined and handled and the resulting large volumes of solid waste must be disposed of in an acceptable manner.

The hydrogenation process may be direct, indirect, or by pyrolysis, either alone or in combination. In the direct process, hydrogen at high pressure is used whereas steam is used in the indirect process. The pyrolysis process involves heating the raw hydrocarbon source until it thermally decomposes into its several products.

In the book "Synthetic Fuels" (REF) the various conversion processes are defined and described in detail. The process selected is usually based on a variety of chemical and physical properties of the raw fuel and these properties and the conversion process characterize the products which are generated.

There is a variety of types of coal in the U.S. whereas there are two principal types of oil shale, namely that from the Green River Formation and black shale. The oil shales contain "kerogen" which is not a member of the petroleum family but contains a high-molar-mass organic material. The major part of the oil derived from "kerogen" is obtained from pyrolysis.

Tar sands contain a high-viscosity crude hydrocarbon in the form of bitumen which is a member of the petroleum family. The U.S. is not a major source of tar sands although extensive deposits have been identified in Canada.

Various forms of biomass can be converted to synthetic fuels and the production of alcohol from the fermentation of grain is a good example. However, in the U.S., grain is looked upon more favorably as a food stuff rather than as an energy source. Wood is a biomass energy resource but it is not known whether or not it can be used on an economic basis.

The world's supply of non-renewable energy resources are primarily in the form of coal, i.e. approximately 80 percent. Of these, about 25 percent is found in the U.S. Thus, the U.S. is in a most favorable position in terms of its identified coal reserves.

In applying various synfuels technologies to the conversion of coal to synfuels, the thermal efficiencies are about 40-50, 60-65, 65-70, and 70-75 percent for indirect liquefaction, gasification, direct liquefaction, and solvent refining, respectively.

Oil shale is found non-uniformly in the world with approximately two-thirds identified in the U.S. Of the remainder, Brazil has about one-quarter with smaller quantities found in several other countries. It is not certain how effectively and efficiently synfuels can be produced from these identified resources of oil shale.

Tar sands are found in various countries in the world with major resources found in Canada, Venezuela, and the U.S.S.R. The U.S. has relatively minor quantities located almost exclusively in Utah. Unless newer and more efficient conversion processes are found, the U.S. resources will not support other than relatively small production efforts.

Thus far, there are no full-scale synfuels plants in operation in the U.S. However, there are a sizable number operating in various other countries and some have been in operation for a number of years.

The U.S. does have several pilot plants in operation or in advanced preparation for operation. This is important experimentally in that actual samples of effluent and other source terms can be obtained for use.

With the current circumstances, health and environmental protection research can continue on a concurrent basis with engineering development of synfuels technologies. These protection efforts, hopefully, will come to fruition in time to guide decisions regarding full-scale production methods and priorities among them. Results of such efforts can help provide guidance in control technology, avoidance of accidents, remedial actions to spills and other contaminating events, and appropriate modification of the process and the product.

As summarized by Gray and Drucker (REF), various epidemiological studies and toxicological research on several synfuels conversion processes have suggested that the products may have carcinogenic properties as well as greater acute and chronic toxicity when released to the environment as compared to crude petroleums.

Obviously, as with any new technology, it behooves us to fully evaluate synfuels technologies before they are extensively used in the U.S. We must understand their nature and characteristics and develop the appropriate data base to document their health and environmental effects and thus undergird the development of regulatory standards and strategies.

Risk analysis is a useful tool in this effort and can be used to predict health and environmental consequences as to their frequency, characteristics, and severity.

An initial step in the process of assessment (risk analysis) is the identification and quantification of the possible source terms from the various synfuel technologies as well as from the handling and use of the synfuels themselves. Information and data in this regard are contained in a series of four reports produced by TRW Energy Technology Division (REF).

Three of the reports provide estimates of source terms for liquid synthetic fuel technologies whereas the fourth contains an analysis of the various aspects associated with utilization of synfuel products. Results are given in terms of RAU's. In the three conversion process reports (REF) the technologies are described and some eight processes are discussed. For example, in the direct coal liquefaction process, H-coal, SRC-I, SRC-II, and the Exxon Donor Solvent methods are covered; in the indirect coal liquefication process, Fischer-Tropsch synthesis via Lurgi and Koppers-Totzek gasification methods are presented; and the TOSCO II and Paraho processes are contained in the report on oil shale extraction.

3REF

The fourth report, "Source Term Estimates for Synthetic Fuels Technologies" Analysis of Product Utilization"(REF), characterizes the products produced by the eight synthetic fuels processes described in the companion reports, discusses the likely mode of transportation, and describes the end uses of each product.

III. ASSESSMENT OF SYNFUELS TECHNOLOGIES

The assessment of synfuels technologies is complex due to the multitude of potential effluents and their chemical and physical forms, the various media these are in, the effects of process parameters, and the uncertainty as to which technology may reach commercial scale and begin production. Thus, the approach has been to examine all feasible technologies as their development progresses.

Our interest is assessment of the health and environmental effects of the synfuels technologies as they relate to the workers in the conversion process and to the public and the environment due to potential impacts resulting from the synfuels technology or the use of synfuels. This is a broad scope but is critical in establishing pertinent regulatory standards and controls.

In order to deal with the multitude of chemicals involved in the effluents and products of synfuels technologies, the approach was taken to group these in categories which were designated as Risk Assessment Units (RAU)(REF). The procedure would then be to select a representative chemical component from an RAU for studies of effects. This process would then make the system manageable and allow progress to be made in the research and development in a reasonable time frame.

The RAU's were designated based primarily on their chemical characteristics. Of course, other factors could be used, such as technology production parameters or health and environmental effects. The list of RAU's is shown in Figure 1 and had 38 categories.

The work on the RAU concept and its development was done by a group of researchers in the field during 1981 with the final list completed early in 1982.

This concept proved very useful. It permitted a rational grouping of the myriad of chemical compounds potentially produced and emitted from a synfuel site. Thus, it provided common analysis categories for the assessment of health and environmental effects.

The RAU concept was reviewed by a Peer Review Group in early 1983 and one of its comments is paraphrased below:

> The RAU concept adopted for health and environmental assessments seems to be a workable compromise between the overwhelming problem of dealing with a large number of chemicals on a case-by-case basis and the intractable problems associated with risk assessment of complex mixtures. The approach has certain limitations, e.g. the toxicity of an RAU category for one industry may be quite different than that of the same category for another industry, but these difficulties seem surmountable if rigid estimates of RAU toxicity are avoided. The rationale provided for use of RAU's was straightforward and reasonable, chemical categorization must be compatible with analytic methods, and categories should be mutually exclusive and collectively exhaustive.

The work on RAU's was done under the direction of the Integrated Health and Environmental Risk Analysis Program (IHERAP) of the Office of Research and Development (EPA). Its functions were reorganized and work was launched early in 1981. Research was performed both at EPA facilities and under contract with appropriate outside organizations. Major groups involved with this work are:

Industrial Environmental Research Laboratory - Research Triangle Park, North Carolina

Environmental Research Laboratory - Corvallis, Oregon

Environmental Research Laboratory - Duluth, Minnesota

Environmental Research Laboratory - Athens, Georgia

Brookhaven National Laboratory - Upton, New York

Oak Ridge National Laboratory - Oak Ridge, Tennessee

Los Alamos National Laboratory - Los Alamos, New Mexico

Comparative Animal Research Laboratory - Oak Ridge, Tennessee

University of Wyoming - Laramie, Wyoming

Georgia Institute of Technology - Atlanta, Georgia

Tennessee Valley Authority - Chattanooga, Tennessee

There were also other major interests and programs in synfuels technologies and their health and environmental effects. These were undertaken by the:

U.S. Department of Energy

National Institute of Occupational Safety and Health

U.S. Synthetic Fuels Corporation

Mechanisms to provide effective coordination and cooperation in appropriate common areas of work were established early in the program effort. There were frequent contacts and meetings amongst researchers as well as exchanges of correspondence and reports, liaison meetings, and joint research conferences. In most cases, representatives of the Federal agencies participated in each others meetings in synfuels related work.

A chronology of major events in the history of the Integrated Health and Environmental Risk Analysis Program for Synfuels is presented as Figure 2. It includes important events in the management and direction of the program and covers such things as Peer Review Group meetings, User Review Meetings and Workshops. Details of these events are contained in the project files and/or reports published in the scientific literature.

Work was needed to identify potential health and environmental adverse effects, quantify the nature and characteristics of these effects, transform these quantitative estimates of hazards into estimates of risks to man and the environment, and develop effective regulatory standards and control procedures.

Food chain work was done at the Comparative Animal Research Laboratory in Oak Ridge and consisted of studies on uptake, distribution, and retention of selected RAU chemicals by cows, swine, and poultry. The plant uptake, distribution, and retention studies of a terrestrial nature were done at the Environmental Research Laboratory, Corvallis, whereas the work related to aquatic species was performed at the University of Wyoming and at the Environmental Research Laboratory, Duluth.

The occupational health and safety aspects of the program were a cooperative effort by Brookhaven National Laboratory and Los Alamos National Laboratory.

Epidemiology and medical effects evaluation of the synfuels technologies were performed at Brookhaven National Laboratory and this Laboratory was also responsible for the risk analysis for health effects.

The environmental assessments were a function of Oak Ridge National Laboratory as was the risk analysis for environmental effects.

Work on synfuels technologies from the engineering viewpoint and in atmospheric effluents was centered at the Industrial Environmental Research Laboratory, Research Triangle Park. The Tennessee Valley Authority also had a roll in the area of synfuels technology due to their work in energy production.

The Environmental Research Laboratory, Athens was involved with the water pathway and especially work on the modeling of synfuels chemicals.

Certain management functions including responsibility for Workshops and the Peer Review Process were located at the Georgia Institute of Technology.

FIGURE 1

RISK ASSESSMENT UNITS

NUMBER	CATEGORY	DESCRIPTION
1	Carbon Monoxide	CO
2	Sulfur oxides	SOx
3	Nitrogen oxides	NOx
4	Acid gases	H_2S, HCN
5	Alkaline gases	NH_3
6	Hydrocarbon gases	Methane through butanes, acetylene, ethene through butenes; C_1-C_4 alkanes, alkenes, alkynes and cyclo compounds; bp $<\sim 20°$ C
7	Formaldehyde	CHO
8	Volatile organochlorines	To bp $\sim 120^{o}$ C; CH_2Cl_2, $CHCl_3$, CCl_4
9	Volatile carboxylic acids	To bp $\sim 120^{o}$ C; Formic and acetic acids only
10	Volatile O&S heterocyclics	To bp $\sim 120^{o}$ C; Furan, THF, thiophene
11	Volatile N heterocyclics	To bp $\sim 150^{o}$ C; pyridine, piperidine, pyrrolidine, alkyl pridines
12	Benzene	Benzene
13	Aliphatic/alicyclic hydrocarbons	C_5 (bp $\sim 40^{o}$ C) and greater; paraffins, olefins, cyclocompounds, terpenoids, waxes, hydroaromatics
14	Mono/Diaromatic hydrocarbons (excluding benzene)	Toluene, xylenes, naphtahlenes, biphenyls, alkyl derivatives
15	Polycyclic aromatic hydrocarbons	Three rings and greater; anthracene, BaA, BaP, alkyl derivatives
16	Aliphatic amines (excluding N-heterocyclics)	Primary, secondary and tertiary nonheterocyclic nitrogen, $MeNH_2$, DiMeNH, TriMeN
17	Aromatic amines (excluding N-heterocyclics)	Anilines, naphthylamines, amino pyrenes; nonheterocyclic nitrogen
18	Alkaline nitrogen heterocyclics ["azaarenes"] (excluding "volatiles")	Quinolines, acridines, benzacridines; excluding pyridines

FIGURE 1 (Cont.)

NUMBER	CATEGORY	DESCRIPTION
19	Neutral N, O, S heterocyclics (excluding "volatiles")	Indoles, carbazoles, benzofurans, dibenzothiophenes
20	Carboxylic acids (excluding "volatiles")	Butyric, benzoic, phthalic, stearic
21	Phenols	Phenol, cresols, catechol, resorcinol
22	Aldehydes and ketones ["carbonyls"] (excluding formaldehyde)	Acetaldehyde, acrolein, acetone, benzaldehyde
23	Nonheterocyclic organo sulfur	Mercaptans, sulfides, disulfides, thiophenols, CS_2
24	Alcohols	Methanol, ethanol
25	Nitroaromatics	Nitrobenzenes, nitropyrenes
26	Esters	Acetates, phthalates, formates
27	Amides	Acetamide, formamide, benzamides
28	Nitriles	Acrylonitrile, acetonitrile
29	Tars	
30	Respirable particles	
31	Arsenic	As, all forms
32	Mercury	Hg, all forms
33	Nickel	Ni, all forms
34	Cadmium	Cd, all forms
35	Lead	Pb, all forms
36	Other trace elements	
37	Radioactive materials	Ra-226
38	Other remaining materials	

need to get sev. locations

FIGURE 2

IHERAP CHRONOLOGY

TIMEFRAME	EVENT	PLACE
November 17-18, 1980	Scoping Meeting	Oak Ridge, TN
March 3, 1981	Reorientation Memo	Washington, D.C.
April 21-22, 1981	Dixon Committee Meeting	?
May 13-15, 1981	Categorization of Chemical Compounds and Combustion Products	?
August 17-18, 1981	Combustion Product Testing	?
October 5, 1981	Preliminary Report on RAUs	Oak Ridge, TN
November 4-5, 1981	User Review Group	Washington, D.C.
November 18-19, 1981	Peer Review Group	Knoxville, TN
January 25, 1982	"Final" List of RAUs	Washington, D.C.
May 6, 1982	Peer Review Panel (Health Effects)	Upton, NY
May 18, 1982	Peer Review Panel (Food Chain)	Oak Ridge, TN
September 23-24, 1982	User Review Group	Washington, D.C.
March 29-30, 1983	Peer Review Group	Alexandria, VA
October 27-28, 1983	Peer Review Panel (Food Chain)	Corvallis, OR
December 14-16, 1983	User Review Group	Washington, D.C.
May 5, 1984	Program Suspended	Washington, D.C.

IV. OCCUPATIONAL ASSESSMENT

Due to the lack of large-scale operational synfuels plants in the U.S. it was necessary to utilize other facilities, with some comparable characteristics, to study the occupational aspects of synfuels technologies. The other approach was to identify and use a large-scale synfuels plant located in another country. Both approaches were instituted and are represented by studies on coke-oven workers and workers at the coal gasification plant in Oblic,Yugoslavia, Autonomos Province of Kosovo, which is operated by Elektroprivreda Kosovo.

The purpose of these studies was to relate occupational exposures of workers to synfuels chemicals (or comparable industrial chemicals) to various health parameters which may be identified and measured. Thus, the coke-oven worker population was to serve as a surrogate population for an actual worker population engaged in a synfuels technology.

COKE-OVEN WORKERS

The rationale for selecting the Pittsburg coke-oven workers for study (surrogate group) was the similarity between the exposures to toxic substances in coal hydrogenation technology and coal conversion to coke. Also, there is a large amount of epidemiologic data available on the coke-oven population and it demonstrates the risk of respiratory and genitourinary malignant disease is significantly increased.

Another fundamental reason for a study of the synfuels industry was the desire to demonstrate the usefulness of a unique approach to health and environmental risk analysis. Thus, while the industry is being developed on a small-scale basis the analysis of its technology, products, and waste streams as to their health and environmental effects should provide a solid basis for environmentally sound practices in technology development.

At the time, there were plans being made to conduct a large-scale epidemiological study of coal gasification workers in Yugoslavia. The coke-oven worker study would thus serve as a small-scale pilot study in which to use, evaluate, and modify, if needed,based on experience the proposed methodology of the Yugoslavian project.

The four objectives of the pilot study are taken from an unpublished report "Coke-Oven Workers Study" (REF).

1. To evaluate the epidemiological and clinical methodologies to be used in the Yugoslavian project.
2. To identify, if possible, potential occupationally-related morbidity effects.
3. To provide information to be used in the Integrated Health Risk Analysis Program based on human exposure to chemicals that represent risk assessment factors or are surrogates for Risk Assessment Categories (RAU's).
4. To provide data on the upper levels of health impact of synfuels related production and processes for input into an Integrated Health Risk Analysis. These data relate work site exposures to relevant pollutants and toxicants to the health status of workers and neighboring populations.

The initial plan was to evaluate coke-oven workers with 20 years employment with a minimum of five years "topside" exposure, and control subjects, matched by age, sex, race and cigarette smoking history, employed for 20 years in the same plant but never as cokers, i.e. non-exposed.

Planning also called for the transport of the members of the study population to the Medical Research Center at Brookhaven National Laboratory for three days of medical evaluation including standard clinical tests plus more recently developed test procedures. These new procedures included cytogenetics (chromosomal aberrations and sister chromatid exchange), in vitro cultures of hematopoietic percursor cells (CFU_c, BFU_e, CFU_e), ventilation - perfusion lung scans, and benz-a-pyrene DNA adducts measured in peripheral blood cells. Each person would also have a complete occupational chemical exposure profile determined.

The report (REF) describes the Pittsburg coke-oven workers study. It presents in detail the rationale and objectives of the study, the selection of workers, clinical health assessment procedures, and exposure assessment procedures. The report also compares the actual study outcomes to the expected outcomes and discusses lessons learned from the actual processes. These lessons are then to be applied to the final designs of the Yugoslavian study as well as any future planned, similar U.S. studies. Finally, the text concludes with descriptions of the study findings and recommendations.

Several very important lessons were learned from this study. There was a very severe selection bias of both workers and controls due to a variety of reasons. These included the effects of a recent strike, financial loss to take the several days needed to participate in the study, and the inconvenience of traveling to New York for the clinical evaluation. These and other causes also minimized the number of workers willing to participate.

It was also most difficult to obtain any meaningful exposure data on workers. Causes included many uncertainties in obtaining occupational histories, lack of information on specific exposure histories, and the inability to make arrangements for the collection of pertinent samples in the work place.

Also complicating this situation is the meager amount of information in the literature on exposures of workers to specific chemicals. Exposure data are generally available as a coal tar pitch volatile measurement which is a non-specific analytical procedure for monitoring benzene or cyclohexane soluble compounds and thus not very useful for addressing exposures in terms of specific chemical species (RAU's). Thus, it was not possible to develop useful exposure profiles for the individuals studied.

A large amount of time, over an extended period, was devoted to negotiations with industry management and union representatives. Also, industry management, although willing to comply with the law or union contract clauses in the release of information, will not release information which may be detrimental to future negotiating positions or pollution standards. The lesson is that future U.S. studies must identify other mechanisms to obtain the understanding and cooperation among the workers that the benefits of participation in health effects studies are important to the worker, his family and his co-workers.

These lessons learned were carefully reviewed as to guidance for the Yugoslavian study. The factors involved are different between the two sites. There will be complete and full participation by management and the workers and thus, no self-selection bias. Work dossiers, containing a record of all lifetime employment, are maintained for each worker.

A clinic and a laboratory are fully staffed and available for worker medical examinations as well as specimen collection and analysis. Also, at the Kosovo Plant and at control sites, exposure data will be obtained by actual industrial hygiene sampling measurements.

Conclusions, in addition to those summarized as lessons learned, are given below (REF):

> Complete cooperation by workers and management is necessary for the success of any in-depth health assessment evaluation of workers for morbidity. The health evaluation and occupational history exposure questionnaires were satisfactorily validated. Information was obtained on several new experimental clinical evaluation test procedures as predictors of disease. New information was obtained and understanding improved regarding basic mechanisms and synergistic effects that coke-oven emissions (complex mixtures) have on human health. Epidemiologic study methodologies, full-scale retrospective and prospective, were substantiated.

KOSOVO COAL GASIFICATION PLANT WORKERS

The Kosovo coal gasification plant was selected for study due to the facts that it was readily available for study and was a large-scale operating facility which has been in use since 1973. It employs Lurgi technology of East German design and produces high BTU commercial gas as well as several other products.

The research study is a joint cooperative effort of the U.S. Environmental Protection Agency, the U.S. Department of Energy, and the National Institute of Occupational Safety and Health in the United States and various groups in Yugoslavia including Institute Kosovo, University of Kosovo (formerly University of Pristine), Forestry, Veterinary Medicine and Agriculture, Institute for Medical Research and Occupational Health, and with the cooperation and assistance of Elektroprivreda Kosovo which operates the coal gasification plant in Oblic (outside Pristina) in the Autonomous Province of Kosovo.

United States interest in the study of this Yugoslavian synfuels plant center around three areas:

1. An occupational health study of workers in an actual operational facility before one is placed in operation in the U.S.
2. Possible generic use of the results in the continuing health and environmental evaluation of synfuels technologies.
3. A long-range interest in continuing the policy of cooperative scientific exchanges with Yugoslavia.

Of course, it is well recognized that the Kosovo plant is of an old design and has limited pollution control features. However, results could represent a "worse case" exposure situation which could provide valuable information for use as guidance in the design, construction, and operation of coal gasification plants in the United States.

The coal gasification plant is operated as part of a large industrial complex. Part of the gas produced is used partly for fuel and partly for fractionation; that is, for the recovery of hydrogen which is further used for ammonia synthesis. The fraction of gas after hydrogen recovery is enriched with methane which is mixed with the remainder of pure gas.

Major components of the coal gasification plant are:

1. Six generator units.
2. A condensation plant.
3. A rectisol plant for purification of raw gas.
4. An air separation plant (oxygen and hydrogen are produced).
5. A tar and medium oil separation plant.
6. A phenol separation plant.
7. A plant for biological treatment of waste waters (not operated).

The coal for the conversion process is obtained from several strip mines located nearby. These mines produce lignite coal which is pulverized and dried by the Fleisner drying procedure before use in combination with oxygen and superheated steam at a pressure of 23 bars and a temperature of $350^{o}C$.

Previous cooperative work with the Kosovo facility has been done for many years by the EPA's Industrial Environmental Research Laboratory - Research Triangle Park, NC. Much of these efforts was to characterize process streams and fugitive emissions at the gasification plant.

The basic purpose of the study was to conduct an occupational health assessment of workers engaged in a coal gasification facility as one of the synfuel technologies. It would thus provide an opportunity to assess the impact of a coal gasification facility on the health of its workers and the community adjacent to the facility; to evaluate the feasibility and acceptability of present safety and health standards for the protection of workers and the applicability of work practices and control procedures; and to obtain needed information and data well in advance of large-scale synfuels technology development in the United States.

Initial efforts were initiated in 1980 to evaluate the health consequences that the coal gasification imposed on the workers and the local, general population with the work to be done by the Yugoslavs. In 1983, a second phase joint cooperative effort to be conducted by investigators from the U.S. and Yugoslavia was negotiated. It was to be a comprehensive health effect study consisting of industrial hygiene (exposure), epidemiological, and clinical components.

The industrial hygiene program was designed to characterize the chemical and physical stresses in the workplace; investigate the use and effectiveness of engineering control systems, and employee and administrative work practices;

evaluate plant and comparison populations exposures; special studies to assist the clinical and epidemiology programs; develop information and technology transfer between U.S. and Yugoslavian coal gasification plants; initiate technology transfer to Yugoslavs for subsequent routine monitoring; and accomplish communication, liaison, and logistic activities with the Yugoslavs as needed.

The purpose of the investigations of the health effects of exposure was to evaluate the potential health impact of the plants' operation on the workers and the general public. Effects of exposure to various chemicals in the working environment were to be studied in detail in the exposed and control workers. Detailed assessments of selected workplaces in the generator plant, phenolsolvan plant, and rectisol plant were to be made. Similar procedures were to be employed to any population exposed to various contaminants. The industrial hygiene studies, carried out concurrently with the clinical and epidemiological investigations, will allow the establishment of a cause/effect relationship between the presence of chemical substances and health impairments, if such are observed.

Progress and the status of these research efforts are discussed in a report by Morris (REF). He also discusses the background of this cooperative work including the agencies and groups involved and the specific responsibilities of individual organizations. According to Morris, the responsibility for industrial hygiene and exposure monitoring were split among BNL, LANL, and the NIOSH Morgantown, WV, laboratory whereas the BNL had responsibility for health effects and epidemiology.

The protocol or the July, 1984 characterization campaign was reported by Jackson (REF) and he also presented the strategy for the industrial hygiene personnel sampling campaign to begin in March, 1985 (REF).

Detailed plans for the research on health effects and epidemiology were prepared by the BNL (Morris). Early efforts in these areas address respiratory illnesses and skin cancer.

It should be borne in mind that essentially all these efforts were truly cooperative ventures between Yugoslavian and American Scientists and support personnel. The expertise of each country was brought to bear in the most effective manner.

These studies are continuing although certain preliminary results and conclusions have begun to appear. For example, an entire session of "The 1985 American Industrial Hygiene Conference" in Las Vegas, NV in May was devoted to the title "Occupational Health Study of the Kosovo Yugoslavia Coal Gasification Plant". (REF) Papers ranged from an overview of the study, a description and discussion of the Lurgi process at Kosovo, to the details and results from the industrial hygiene, clinical, and epidemiological studies. The authors of these papers were about equally mixed between Yugoslavia and the United States.

V. ENVIRONMENTAL ASSESSMENT

To evaluate the exposures and effects of synfuels chemicals on health and the environment, it is necessary to determine whether or not these materials are taken up and retained in the food chain. For practical purposes the food chain is divided into two major categories, namely terrestrial and aquatic. In addition, for the terrestrial category it may be conveniently subdivided into plants used for food and food-producing animals.

The work on food-producing animals was performed by the Comparative Animal Research Laboratory (Oak Ridge Associated Universities) in Oak Ridge, TN. This was an experimental effort to determine and evaluate the significance of food chain contamination by synfuels technologies by studying metabolism and retention of synfuels chemicals in chickens, pigs, and cows.

The goal was to develop data for use in the food chain analysis of synfuels-related chemicals by determining the uptake and biological retention of RAU compounds in food-producing animals (dairy cattle, swine, and poultry) and obtaining the transfer coefficients required for food chain exposure assessments. These species of animals are widely used by humans for supplies of meat, milk and eggs.

Specific goals of the project were:(REF)

1. Determine the biological retention of representative compounds following acute and chronic oral administration of food-producing animals; determine the accumulation and loss of these compounds in consumable products following an acute dose; and determine the rate of accumulation in tissues when they are administered chronically.

2. Determine and employ practical methodology for the isolation and quantitation of selected compounds that are representative of the major chemical classes found in synfuels products and waste materials.

This laboratory was also involved in the early research of plant uptake of synfuels chemicals. The goal of this phase of the work was to determine the extent of uptake, transport, and concentration of representative compounds in selected vegetable crop species commonly used by man as foods. Included within the test plant selection was broad physiological and morphological diversity with reference to the plant organ used for human consumption.

The report by Eisele represents a good (REF) summary of the rationale for the research, materials selected for study, procedures used in both acute and chronic studies, sampling, analysis, and radiometric methods, species of animals utilized in the experiments, and certain results obtained for several RAU compounds.

Data for studies of naphthalene (RAU#14), naphthol (RAU#21), and 7-methylbenz (c) acridine (RAU#18) indicate that all three compounds are transferred to and found in various animal products, i.e. milk, eggs, and meat. Thus, for these chemicals there is a potential risk from the food chain. Similar results were obtained for studies of B a P (RAU#15) in chickens and pigs.

Early research work by this group using a hydroponic experimental system demonstrated that pea, onion, and lettuce plants took up naphthalene, naphthol, and 7-methylbenz (c) acridine and that the parent compound or its metabolites reached the edible portion of the plant in a relatively short time.

Other results from this group have been reported in the literature (REF). These data cover work on other synfuels chemicals, such as aniline (RAU#17) and indole (RAU#19), as well as additional information on the total program and its results.

These other synfuels when used in feeding experiments demonstrate an accumulation and retention of them or their metabolites in consumable meats, eggs, and milk. Of course, in all the synfuels feeding experiments performed there is a difference in species and in tissue distribution and concentration. This suggests that exposures would depend upon the quantity of contaminated food consumed as well as the specific product involved.

PLANT SECTION

The terrestrial plant research was located at the Environmental Research Laboratory, Corvallis, OR. The overall goal of the plant research program was to obtain an understanding of the mechanisms of xenobiotic chemical uptake, translocation, accumulation, and metabolism in plants. This knowledge was then applied to the various chemicals associated with the several synfuels technologies. Models were developed which coupled the plant data with the movement of water, photosynthates, and mineral nutrients to predict vegetational bioaccumulation and food contamination and thus a portion of the environmental fate of toxic chemicals (synfuels). (REF)

This same report presents a description of problems and the proposed research approach, the outline of root uptake studies for screening and of whole plant studies for more detailed information, and of the design and diagrams of the automated environmental exposure chambers to be used in the research.

An internal report (REF), "Plant Exposure Laboratory and Chambers" presents details on the design, construction, and operation of the laboratory and the exposure chambers. The objective was to be able to do plant uptake studies in a manner in which toxic and radio-labeled chemicals could be contained and controlled in an environment where plant physiological parameters can be observed and positively managed. This report also contains appendices which address the computer programs devised to manage the equipment in and data from the exposure laboratory; the source code and description used for the control program; details of the construction drawings and parts list pertaining to the plant exposure chamber; the diagrams for electronic components of the laboratory; details of the construction and calibration of the thermistor used for temperature regulation; and the construction of the hydroponic plant nursery as well as the recipes for several nutrient solutions. Other computer management and calculational programs were developed to assist in the accomplishment of the experimental work.

Initial screening work was done using excised roots of barley plants to learn the uptake characteristics of toxic organic chemicals. A number of papers describe the experimental procedures (REFS. 10 & 11 from Corvallis) and the results obtained with a number of synfuels chemicals (REFS PERTAINING TO ROOTS). The paper by McFarlane and Wickliff (REF#8) is a summary of their work in using excised barley roots for uptake studies of several organic chemicals labeled with carbon-14. Chemical uptake rate constants for the chemicals tested were ranked in the following order: captan $\simeq$ phenol > aniline > ethanol $\simeq$ indole $\simeq$ trifluralin $\simeq$ propanil > 1, 2,4-trichlorobenzene (TCB) > nitrobenzene $\simeq$ atrazine > bromacil > simazine > monuron. Thus, captan was taken up more rapidly than the other chemicals studied. Such studies, of course, do not represent uptake of chemicals from soil into whole, intact plants but they do represent a valid plant/chemical interaction which forms part of the complete system of chemical-plant kinetics, as noted by the authors.

Whole plant uptake studies have been completed with bromocil, phenol, nitrobenzene, captan, and butanol and others are scheduled. The results of studies for uptake of nitrobenzene and bromacil by hydroponically grown mature soybean plants are discussed in a presentation by McFarlane et. al. (REF#3).

Related to this plant work was the development of a computer searchable data base on the Uptake, Translocation, Accumulation, and Biodegradation of Organic Chemicals in Plants (UTAB). A description of this data base and its use is contained in a paper presented at the Annual Plant Physiology meeting in July, 1985 (REF). This data base was developed as an expansion of a data base, PHYTOTOX, developed at the University of Oklahoma.

Another output of the Corvallis research was the development of a plant uptake model. This model was described in a paper, "A Mathematical Model of the Bioaccumulation of Xenobiotic Organic Chemicals in Plants", by McCoy et.al. (REF). The long-range plan is to parameterize this model for various plants and couple it with a soil model to allow prediction of plant uptake on the basis of chemical parameters.

The Environmental Research Laboratory, Duluth and the University of Wyoming have been responsible for the work on aquatic toxicity data for synfuels process waters. The emphasis in this cooperative effort has been on aquatic hazard assessment of untreated process waters likely to be discharged, treated process waters, and process water fractions.

Primary and secondary objectives are taken from a paper by Biesinger, et. al. (REF):

Primary Objectives:

1. Evaluate the aquatic toxicity of potential untreated discharges from oil shale processing, coal gasification and tar sands extraction, emphasizing mine drainage waters, raw and spent oil shale leachates, and untreated process waters to be discharged to spent oil shale or ash piles.

2. Evaluate the aquatic toxicity of treated process waters from pilot-scale water treatment methods for oil shale processing, coal gasification and tar sands extraction, including retort, condenser, blowdown and air treatment wastewaters.

3. Identify principal toxic fractions and constituents in process waters studied under Objectives 1 and 2 from oil shale processing, coal gasification and tar sands extraction.

Secondary Objectives:

1. Compare chemical and toxicological characteristics of process waters from advanced fossil-fuel processing technologies to determine similarities and differences as a basis for minimizing needs for further toxicology characterization and for simplifying design requirements for treatment technologies.

2. Advance the state-of-the art in aquatic toxicology by comparing results of traditional methods (e.g., 96-hour flow-through acute, embro-larval, and lie cycle tests) with new candidate procedures which may be more sensitive or serve other testing objectives (e.g., pathology, behavior population - level and community-level tests).

This paper also presents results obtained, a proposed complex effluent hazard assessment scheme, and a summary of conclusions to date. These conclusions are that:

Oil shale process water toxicities are similar within groups.

Oil shale process water treatment effectiveness varies.

Raw oil shale leachate toxicities vary, depending on shale source.

Oil shale mine waters appear to be non-toxic.

Few data are available on spent oil shale leachates and shale oils.

Underground coal gasification process water toxicities are similar.

Tar sands process waters are less toxic than oil shale and coal conversion process waters.

Hazard assessment protocols are needed for synfuel - related products and waters.

A later report by Bergman and Meyer (REF) in 1983 summarizes two years of research in aquatic ecosystem effects of process waters produced by synthetic fuel technologies. A major conclusion is that there is wide variation in the toxicity of various waste waters and, therefore, each must be evaluated individually. The report also contains some information related to possible treatment methods to reduce biologic toxicity.

Another aspect of this part of the research has been the development and operation of two information and data storage and retrieval systems. The first is titled AQUIRE for Aquatic Information Retrieval Data Base (REF). The objectives of this system were to provide a comprehensive, systematic, computerized compilation of aquatic toxicity data for single compounds, and to analyze toxicity data on sufficient chemicals and organisms to provide comparisons among organisms, chemicals, and test endpoints.

The second data base is named CETIS for Complex Effluents Toxicity Information System (REF). The objectives of this system parallel those for ACQUIRE except that CETIS deals with complex effluents rather than single compounds.

Both of these data storage and retrieval systems are parts of the much larger data base systems in use by the Environmental Protection Agency. These programs are coded to facilitate ready access to the various data bases which comprise the total system.

VI. HEALTH ASSESSMENT

It was, of course, recognized early on that synfuels technologies would produce a multitude of chemical products some of which would have adverse effects on biological systems, including people. Therefore, it was necessary to evaluate these chemical entities to determine those which were harmful, at what levels, and under what conditions.

Wide ranges of test procedures using a variety of biological end points have been studied. For convenience, these can be divided into relatively short-term screening studies and those of long-term duration which usually are more definitive, more resource intensive, and require considerably longer to complete and evaluate.

The short-term screening tests have included in vitro assays using various species and strains of bacteria for the detection of toxicity, mutations, and chromosome damage and recombination. Similar assays have detected toxicity, mutation, cell transformation, and chromosome damage utilizing cultured mammalian cells as the test organism.

Health studies of a long-term nature have used whole animals, especially rodents, to evaluate reproductive effects, skin carcinogenicity, inhalation toxicology, neurobehavioral toxicology, and teratology and developmental toxicology.

We have also previously reviewed direct observation of humans and human-health-records for biological effects of synfuels technologies. These clinical and epidemiological procedures can be used when a population or worker group has been exposed to relatively high levels of contaminants and is available for direct or indirect study. Occupationally exposed groups fit into these categories as do certain populations that live in the areas adjacent to synfuels facilities which impact the surrounding environs from discharges of synfuels chemicals.

A complicating factor in health effects as well as environmental effects studies is the fact that no actual synfuels products from commercial synfuels technologies facilities are readily available for evaluation. Therefore, products from a few pilot plants can be studied and simulated effluents can be made and used on a surrogate basis. It is recognized that these procedures inherently introduce uncertainties into the bioeffects and environmental effects studies.

The real effluents from synfuels technologies depend on the nature of the resource material, the technology employed, a variety of process parameters, the number and nature of any control procedures, and various features which are site specific. These are desirable problems when one considers the luxury of evaluating a complex energy technology from an environmental protection standpoint prior to its introduction into our industrial society.

The opportunity is thus available to perform health and environmental risk assessments on synfuels technologies during the very early formative and design stages of the technology development. This should be effective in that guidance and any needed controls can be identified early on and used to moderate plant design and operation. The process should be much more effective than waiting for plant design and construction or regulatory pressures based on immediate need.

Information and data on health effects of synfuels chemicals have been presented at a series of annual symposia hosted by Oak Ridge National Laboratory (REF)(list Life Sciences Program Sym). These symposia have included many other aspects of synfuels technologies such as the technology, chemical characterization, environmental transport and effects, occupational health, and control technologies.

The first of these symposia, "Synthetic Fossil Fuel Technology, Potential Health and Environmental Effects" was held in 1978 and the proceedings were published in 1980(REF) (Cowser & Richmond 1980). Seven papers, at this symposium, were devoted to biological effects studies and ranged from short-term mutagenicity studies using bacteria to studies using rabbits and mice to evaluate the toxicological and carcinogenic effects of shale oil products. In many of these studies, as well as others, positive results have been observed on the induction of adverse biological effects in the study species.

The proceedings of the Fifth Life Sciences Symposium, titled "Synthetic Fossil Fuel Technologies, Results of Health and Environmental Studies", was published in 1984 (REF)Cowser 1984) whereas the Symposium was held in 1982. There were some eight papers each devoted to subjects identified in the proceedings as "Toxicology and Transport, Transformation, and Fate". Many of these papers involved in vivo studies whereas one article by Morris, et.al. (REF P.323) addressed the use of comparative approaches in extrapolation to health risk.

A good summary of the bioeffects of synfuels has been published by Rom and Archer (REF 1980) as "Health Implications of New Energy Technologies". They address such areas as coal workers pneumoconiosis and respiratory disease, effects from coal liquefaction, and studies related to the production of liquid fuels from shale oil. There are many adverse health effects which have been noticed and documented.

Health experience from these and other health effects studies needs to be carefully reviewed and evaluated in order that steps can be taken in technology development to:

1. help assure adequate worker protection
2. prioritize and select for further development those processes that present minimal or controllable carcinogenic hazards, and
3. ensure the incorporation of adequate engineering control measures in plant design as operational procedures.

Many other literature citations can be found which deal with health effects studies of synfuels chemicals. Representative ones include an early review of potential impacts of oil shale technology by Slawson and Yen (REF), an article titled "Health Hazards and Pollution" (REF) which deals with chemicals from a coal liquefaction plant, toxicological assessment of refined shale oil using short-term microbial testing by Rae et. al. (REF), a paper by Timourian et. al. (REF) which deals with in vitro and in vivo testing of shale oil products using tests of comparative mammalian genetic toxicology which indicate that carcinogenicity decreases after hydrotreating and that since cytogenetic endpoints can be measured in vitro, in vivo, and in man this test can be used to relate test data to human exposure, and the article by Gray (REF) which reviews the research conducted on health and environmental effects of selected synfuels by Pacific Northwest Laboratories.

Health effects research has effectively demonstrated that various effluents to be expected from the several proposed synfuels technologies can cause a wide variety of detrimental biological effects. These results can be used for guidance in future technology planning as to priorities, control schemes, and evaluation systems.

The frame work to accomplish a comprehensive evaluation of synfuels technologies as well as a comparison of their relative merits is risk assessment. This tool in terms of environmental risk assessment and health risk assessment will be reviewed as to its current status and applicability.

VII. ENVIRONMENTAL RISK ASSESSMENT

Environmental risk analysis has been defined as the process of estimating the probability of adverse changes in the environment which are the result of human activities. This is an emerging field and a lot of effort has been directed towards its development during the past decade.

It was looked upon as a potentially important contributor to decision making in a report by Gove _et_. _al_. in 1982 (REF). These authors indicated the applications by Federal regulatory agencies of risk data for developing regulatory standards. They also pointed out the usefulness of risk analysis elements being integrated into research when appropriate.

ORNL/TM-85

These and other considerations were in mind in establishing the Integrated Environmental and Health Risk Analysis Program for Synfuels somewhat earlier. It was envisioned that pertinent information and data could be developed which would be useful to the Agency in regulatory decision making.

Hopefully, effluent waste streams from a technology process can be ranked by environmental risk; changes in risk level associated with various control technology options can be estimated; sensitivity of risk estimates to variables which are site dependent can be estimated; and areas where further research could reduce the uncertainty in and further refine estimates of risk can be identified.

Early efforts were directed toward identifying toxicological data, quantifying adverse environmental impacts from synfuels chemicals, development of environmental risk assessment methodology, application of the resulting methodology to specific examples of synfuels technology, and identification of areas which required additional environmental research.

An early report (A) by Barnthouse et al, which was titled "Methodology for Environmental Risk Assessment of Synfuels Technologies", described the procedures and methodologies planned to be used for environmental risk assessment for synfuels.

ORNL A

The efforts were scheduled to cover three synfuels technologies (direct coal liquefaction, indirect coal liquefaction, and shale oil extraction), the various Risk Assessment Units, five selected environmental endpoints (reductions in fish populations, development of algal populations, reductions in timber yield, reductions in agricultural production, and reductions in wildlife populations), five possible methods for estimating risk (analysis of extrapolation error, quotient method, fault tree analysis, analytic hierarchy process, and ecosystem uncertainty analysis), and comparisons of the results derived from the various methods for risk estimation. These efforts were discussed in detail by Barnthouse et. al (A) and periodically by the ORNL researches in progress reports, such as (D)and (B), which were made to the EPA Project Officer.

ORNL A

ORNL D + B

The toxicological data base was obtained from the literature and primarily through the various computer data bases which have been developed in recent years by the EPA and other organizations. The availability of toxicity data for synfuels chemicals has increased appreciably during the last several years.

Since the U.S. does not have any large-scale synfuels plants in operation, it was necessary to simulate several reference environments in which modeling could be done. The report, "Generic Environments for Synfuels Risk Assessments", by Gull and Suter (C) describes in detail the two reference sites selected as well as the alternate site.

ORN C

Thus, the risk assessments are generic in nature in that they are for the purpose of evaluating risks associated with technologies rather than with those associated with specific plants at particular sites. The report (C) also discusses the near-field and the far-field of each reference site with emphasis on the near-field in which significant concentrations of at least some of the synfuels chemicals might be expected to occur.

The following information, pertaining to these reference sites, is from Gull and Suter (C). The important parameters in selecting sites for synfuels technologies are an ample source of synfuels stock of satisfactory quality, a reliable and sufficient supply of water of adequate purity, and industrial interest in developing it as a synfuels facility site.

In each case, the physical description (terrain, meteorology, surface and subsurface hydrologies, and vegetation in the region), ecological populations-at-risk (resident aquatic flora and fauna, resident terrestrial flora and fauna, and nonresident members of these groups), and human populations-at-risk (people residing in the region, people who consume water from the region and people using foodstuffs from or derived from the region) are described and discussed for each of the selected reference sites. Various relevant parameters for these sites are contained in several appendices.

The reference site for the oil shale treatment facility is the region of the Green River Formation of northwestern Colorado, southwestern Wyoming, and northeastern Utah. There are large resources of oil shale in this region and the quality of the deposits is quite high.

For analogous reasons, the generic environment selected for a coal liquefaction site is the region denoted as the Appalachian Basin. This region is centered in eastern Kentucky and western West Virginia. There is a large and ready supply of coal in the region which is undesirable for many other purposes.

These reference sites, the western one and the eastern one, readily meet the resource and water supply criteria and would seem desirable for large scale industrial development if decisions are made to proceed with an oil shale extraction technology facility or a synfuels plant for coal liquefaction. Perhaps obviously, the characteristics of these two reference sites are different as to their physical environments, ecological populations-at-risk, and human populations-at-risk.

An alternate reference site was selected for some synfuels facilities in the Fort Union Basin which is located in northwestern South Dakota, western North Dakota, and eastern Montana. There is an abundance of adequate coal and availability of good water in the region. Again, the characteristics of the physical environment, ecological populations-at-risk, and human populations-at-risk are much different from the two reference sites identified above.

Two earlier draft reports were combined into a single (REF) report (ORNL/TM-8672) by Travis, et. al. It is titled "Exposure Assessment Methodology and Reference Environments for Synfuel Risk Analysis" and was published in 1983. This report presents an exposure assessment methodology for evaluating health and environmental risk from synfuels technologies and provides broad characterization for the two reference environments in which synfuels facilities might be sited. Certain modifications in the environmental assessment methodology and its applications are enumerated in this report.

The methodologies include atmospheric, aquatic, and terrestrial food chain pathways and these are discussed in detail. The atmospheric pathway covers areas up to 50 km and those beyond 250 km from the site. These are well covered by existing models whereas the main problem area is between 50 and 250 km from the site.

The aquatic pathway covers surface and ground waters whereas the terrestrial system includes drinking water, agricultural produce, beef and milk, and default values regarding site specific parameters.

Reference sites are the same as described in the earlier report by Gull and Suter (C). That is, each is described in terms of its physical environment, ecological populations-at-risk and human populations-at-risk.

The report stresses that the methodologies and parameters are generic and intended only for screening purposes. Assessment methodology is described very well and important details regarding the environmental exposure assessment are given. Obviously, the reference sites are used for assessment as no commercial synfuels facilities are currently operational in the U.S.

A report, ORNL/TM-9070 (REF), by Barnthouse, et. al. in 1985 provides an analysis for all 38 RAU's when released on a unit basis into the environment. It provides results of a risk analysis study performed for the 38 categories of chemical contaminants that may be released to the environment by synthetic fuels production facilities. Discussion includes modeling of the environmental transport and fate of contaminants in the atmosphere and in surface water, quantification of risks with respect to the five ecological endpoints in the research protocol, and utilization of the two reference sites.

Using a uniform release rate for comparative purposes, the risk analysis is limited to estimating the relative risks of the various RAU's as functions of their environmental chemistry and toxicology. Tables present the effects on specific endpoints and rank the RAU's accordingly. The rankings are determined by several procedures and differ somewhat in relative values although the rankings are highly correlated.

Barnthouse, et. al. (REF) also identified a number of fairly significant uncertainties in their work. Toxicological data suitable for use in risk analysis are fairly abundant for fish and relatively sparse for other organisms. Frequently, the diversity and lack of comparability of the test systems used limit the utility of the existing data. When considering uncertainty in expected environmental concentrations of synfuels chemicals and predicted effects thresholds for fish to synfuels effluents, the uncertainty of the toxicological effects is much greater than that concerning environmental transport.

The environmental risks associated with several synfuels technologies are presented in three recent reports, ORNL/TM-9074, "Environmental Risk Analysis for Direct Coal Liquefaction" (REF), ORNL/TM-9120, "Environmental Risk Analysis for Indirect Coal Liquefaction" (REF), and ORNL/TM-9808, "Environmental Risk Analysis for Oil from Shale" (REF). The primary purposes of these reports are to help guide environmental research on synfuels technologies by identifying the most hazardous synfuels chemicals and to determine the most important sources of scientific uncertainty regarding the fate and effects of these synfuels chemicals.

As indicated earlier, the strategy involves grouping the effluent synfuels chemicals into representative groupings, RAU's, utilizing reference sites which have characteristics of sites likely to be selected for commercial synfuels sites, and assessing environmental risks in terms of five specific adverse ecological endpoints; namely reductions in fish populations, timber yield (or undesirable changes in forest composition), agricultural production, and wildlife populations, and development of algal blooms that detract from water use.

A synopsis of each report is taken almost verbatim from the reports' summary.

Report ORNL/TM-9074 (REF) on direct coal liquefaction presents results of a risk analysis of four direct coal liquefaction technologies: Exxon Donor Solvent (EDS), Solvent Refined Coal-I (SRC-I), Solvent Refined Coal-II (SRC-II), and H-Coal. All four technologies had equal capacities (2.72×10^4 Mg coal/d) and the same waste treatments. All were located in a reference environment resembling eastern Kentucky. Estimates of concentrations of released contaminants in the air, and surface water of the reference environment were obtained, using a simple Gaussian-plume atmospheric dispersion and deposition model and a steady-state surface water fate model. Concentrations in soil and soil solution were obtained from a terrestrial food chain model.

Risk to the five ecological end points were estimated using one or more of three methods: the quotient method, analysis of extrapolation error, and ecosystem uncertainty analysis. In the quotient method, estimated environmental concentrations were simply compared to toxicological benchmarks such as LC_{50}'s (lethal dose to 50% of population exposed) available for standard test organisms. In analysis of extrapolation error, statistical relationships between the sensitivities to contaminants of the various taxa of fish and between acute-and chronic-effects concentrations were used to estimate, with appropriate error bounds, chronic-effects thresholds for reference fish species characteristic of the reference environment. Taxonomic extrapolations were used to express the acute effects of RACs in terms of a common unit, the 96-h LC_{50} for largemouth bass. The extrapolated LC_{50}'s and the source-term estimates were then combined and used to assess the acute toxicities of the whole effluents from the four technologies. In ecosystem uncertainty analysis, an aquatic ecosystem model was used to compute risk estimates that explicitly incorporate biological phenomena such as competition and predation that can magnify or offset the direct effects of contaminants on organisms.

With respect to fish, nine RACs were determined to be significant for one or more technologies. RAC 5 (ammonia) was the only RAC found to be significant for all technologies, waste water treatment options and analysis methods. RAC 34 (cadmium) was significant for all technologies and water treatment options according to the quotient method and by all three methods for EDS and H-Coal. The whole effluent from the H-Coal technology with conventional water treatment appeared to be the most acutely toxic. For all technologies, conventional pollutants appear to be more hazardous to fish than the complex organic contaminants usually associated with synfuels.

Algal toxicity data were available for only 10 RACs. Because of the diversity of experimental designs and test end points used in algal bioassays, it was not possible to rank the RACs using the quotient method. However, most of the toxicity quotients calculated for algae were lower than the corresponding quotients for fish. Ecosystem uncertainty analysis suggested greater risks of effects on algae than did the quotient method, primarily because reductions in grazing intensity related to effects of contaminants of zooplankton and fish. Both methods indicate that RAC 21 (phenols) and RAC 34 (cadmium) posed a significant risk to algal communities.

Conventional pollutants, especially SO_2 and NO_2, were found to have the greatest potential effects on terrestrial biota. Ground-level SO_2 concentrations for all technologies were within 1 to 2 orders of magnitude of phytotoxic levels, even excluding background concentrations. Gaseous pollutant levels were well below toxic concentrations for terrestrial mammals; however, it was not possible to assess risks to nonmammalian wildlife (e.g., birds). Of the materials deposited on soil, RACs 31 (arsenic), 33 (nickel), and 34 (cadmium) pose the greatest threat of toxicity. However, observable effects are unlikely unless these trace elements are deposited on soils with high background concentrations and chemical properties favoring the solution phase.

The report on indirect coal liquefaction, ORNL/TM-9120 (REF) analyses the risks associated with two indirect coal liquefaction technologies: Lurgi gasification with Fischer-Tropsch synthesis and Koppers-Totzek gasification with Fischer-Tropsch synthesis. The plant configurations evaluated were adapted from design information provided by the developers of the technologies. Both configurations reflect a feed coal capacity of 2.72 x 10^7 kg (30,000 tons) per day. Source terms for atmospheric and aqueous waste streams were based on published process conceptual designs and test data obtained from bench-scale, pilot, or demonstration units. Control technology efficiencies were extrapolated from similar applications in other industries.

A reference environment resembling eastern Kentucky or West Virginia was employed in the risk analyses. Estimates of concentrations of released contaminants in the air, soil, and surface water of the reference environment, were obtained, using a simple Gaussian-plume atmospheric dispersion and deposition model and a steady-state surface water fate model.

Risk to the five ecological endpoints were estimated using one or more of three techniques: the quotient method, analysis of extrapolation error, and ecosystem uncertainty analysis. In the quotient method, estimated environmental concentrations were simply compared to toxicological benchmarks such as LC_{50}'s (lethal dose to 50% of population exposed) available for standard test organisms. In analysis of extrapolation error, statistical relationships between the sensitivities to contaminants of the various taxa of fish and between acute-and chronic-effects concentrations were used to estimate, with appropriate error bounds, chronic-effects thresholds for reference fish species characteristic of the reference environment. Taxonomic extrapolations were used to express the acute effects of all RACs in terms of a common unit, the 96-h LC_{50} for largemouth bass. The extrapolated LC_{50}'s and the source term estimates were then combined and used to assess the acute toxicities of the whole effluents from the two technologies. In ecosystem uncertainty analysis, an aquatic ecosystem model was used to compute risk estimates that explicitly incorporate biological phenoména such as competition and predation, which can magnify or offset the direct effects of contaminants of organisms.

With respect to fish, nine RACs were determined to be significant for one or both technologies. RAC 5 (ammonia) and RAC 34 (cadmium) were the only RACs found to be significant for both technologies and all risk analysis methods. RAC 4 (acid gases) was significant for both technologies, according to the quotient method and analysis of extrapolation error; however, this RAC could not be addressed using ecosystem uncertainty analysis. The whole effluent from the Lurgi-based technology appeared to be somewhat more acutely toxic than the corresponding effluent from the Koppers-Totzek technology. For both technologies, conventional pollutants such as ammonia, cadmium, and hydrogen sulfide appear to be substantially more hazardous to fish than the complex organic contaminants usually associated with synfuels.

Algal toxicity data were available for only ten RACs. Because of the diversity of experimental designs and test endpoints used in algal bioassays, it was not possible to rank the RACs using the quotient method. However, most of the toxicity quotients calculated for algae were lower than the corresponding quotients for fish. Only RACs 33 (nickel) and 34 (cadmium) would be judged significant for any technology using the quotient method. Ecosystem uncertainty analysis suggested greater risks of effects on algae than did the quotient method, primarily because of reductions in grazing intensity related to the effects of contaminants on zooplankton and fish.

Conventional pollutants, especially SO_2 and NO_2, were found to have the greatest potential effects on terrestrial biota. Ground-level SO_2 concentrations for both technologies were within 1 to 2 orders of magnitude of phytotoxic levels, even excluding background concentrations. Gaseous pollutant levels were well below toxic concentrations for terrestrial mammals; however, it was not possible to assess risks to nonmammalian wildlife (e.g., birds). Of the materials deposited on soil, RACs 31 (arsenic), 33 (nickel), and 34 (cadmium) appear of greatest concern for phytotoxicity. However, observable effects are unlikely unless these trace elements are deposited on soils having pre-existing high concentrations of these elements and chemical properties favoring the solution phase.

The third report in this series for oil from shale, ORNL/TM-9808 (REF) presents results of a risk analysis of the Paraho and TOSCO-II oil shale technologies. The source terms were estimated for commercial-scale operations producing 7.9 and 7.6 x 10^6 L/d of syncrude for Paraho and TOSCO-II, respectively. Because of Colorado State regulations, the plants were assumed to have no direct aqueous discharges. All wastewaters were assumed to be used to wet the spent shale, which is landfilled with other solid wastes. The chemical composition of the leachate from this mixture and its transport to ground and surface water were estimated. Atmospheric emissions were dispersed by a Gaussian-plume model, deposited on the landscape, and accumulated in the soil. The analyses, results, and conclusions of this research are intended to be generic and are not estimates of actual impacts of specific plants at specific sites.

The leachate was less dilute in the creek water than in the nearest well. Creek water contained several RACs in concentrations that exceeded a hundredth of measured toxic concentrations for fish, algae, livestock, wildlife, or irrigated crops. They are benzene, mono/diaromatic hydrocarbons, polycyclic aromatic hydrocarbons, alkaline N heterocyclics, neutral N, O, or S heterocyclics, carboxylic acids, phenolics, nickel, cadmium, and total dissolved solids. All of these categories deserve additional attention in future research and assessments; however, total dissolved solids (TDS) is the category that appears most likely to cause environmental problems because its incremental concentration is quite high (290 mg/L) relative to potentially toxic levels, and because the leachate will enter the Colorado River system where TDS is already a problem for both agriculture and aquatic life.

Of the atmospheric emissions, only SO_2 and NO_2 had predicted concentrations in air that were within a factor of 100 of thresholds for effects on growth or yield of flowering plants. Although these gases are unlikely to reduce crop or range yield at the predicted concentrations, site-specific assessments should consider the effects of rough terrain and background pollution levels on concentrations of these gases. Arsenic was predicted to accumulate in soil to concentrations that were greater than a tenth of those that are reported to reduce plant growth.

Future assessments should consider the speciation of the emitted arsenic, transformations in the soil, and background concentrations of toxic trace elements in the soil.

None of the RACs appears to pose a significant threat to wildlife due to inhalation. However, the available data on inhalation toxicology is almost entirely derived from mammals and other taxa, particularly birds that may be considerably more sensitive.

Although they are not considered in this analysis, it appears that construction, mining, and waste disposal are more likely to reduce the productivity of plants and animals than are the emissions from shale processing. Major sources of uncertainty include the composition and transport of leachate from the mixed solid waste and wastewater, effects of accumulation of chemicals in wildlife food chains, effects on nonmammalian wildlife, and effects of terrain on air pollutant concentrations.

IX. USER REVIEW MEETINGS

In order to establish and maintain effective communication between the synfuels research program and the potential users of the knowledge to plan, institute, and operate a regulatory program for synfuels, a system was set up to periodically hold Users Review Meetings.

These Users Review Meetings basically brought together the EPA Project Officer, the various members of the research groups, and the EPA officials representing the components of the Agency which would be involved in developing and implementing a regulatory control program. Representatives from the EPA Headquarters as well as its Regional Offices participated.

Three Users Review Meetings were held. These occurred ? , September 23-24, 1982 and December 14-16, 1983 in Washington, D.C.

Two-way communications were continued between these special meetings by telephone, personal contacts, the exchange of correspondence, and dissemination of reports and other technical documents.

The process served to provide practical and timely input into the research programs and concurrently inform the Users of the status, form, and nature of the research efforts as well as the plans for the future. These efforts were effective and mutually beneficial.

X. WORKSHOPS

In the course of the EPA Integrated Health and Environmental Risk Analysis Program for Synfuels, two workshops were held between experts in risk analysis and those engaged in particular modeling efforts. The first was held in Atlanta, GA in January, 1983 and was titled "A Workshop on Water Modeling Needs and Available Techniques for Synfuels Risk Assessment" (Do and BR, 1983). A second workshop, "Workshop on Food-Chain Modeling for Risk Analysis", was held in Washington, D.C. in March, 1983 (Br and Ba, 1985).

The emphasis of the first Workshop was limited to available "water models". These are models for runoff, surface water, and soil/groundwater which are capable of predicting chemical migration and fate. The characterization of the current approach to synfuels risk assessment led to an identification of the current needs of risk analysts for water models. The principal need is for relatively simple models/techniques that provide estimates of environmental exposure concentrations with an acceptable level of uncertainty.

Of course, if a simple model does not provide the type of information and statistical characterization needed, it is necessary to proceed to more complex models if these are available for application. The workshop participants addressed this issue by contributing to the development of a hierarchy of different levels of available models/techniques, ranging from the simplest possible techniques to the most sophisticated models. Particular models/techniques for each level of the hierarchy were identified, along with a characterization of the modes of transport, transfer, and transformation processes that are considered, and the usually expected uncertainty levels.

The goals of the Workshop and the conclusions reached by the participants are taken from (Do and Br, 1983). The three stated goals were to:

1. Have those currently performing synfuels-related risk assessments describe their needs for models to predict chemical migration and fate in hydrologic systems.
2. Have those currently involved in the development, testing and application of such models respond to these needs by discussing the capabilities and limitations of current state-of-the art water quality and chemical fate models.
3. Provide an overview of the current potential use of water models for conducting risk analysis of chemical releases associated with synfuel technologies.

Presentations and discussions at the workshop indicated that there is a wide variety of water models available for use which range from simple dilution type calculations, through those which may consider advection, dispersion, sorption, volatilization, hydrolysis, photolysis, and biodegradation, to detailed, site-specific models/techniques which generally consider all the key transport, transfer, and transformation processes. These complex models provide higher resolution in space and time, and generally higher accuracy. However, they require a higher level of resource commitment for use.

Conclusions reached include the following:

1. At the present time, risk analysis is primarily comprised of screening level evaluations of alternative technologies, sites, exposure pathways and pollution control options, as opposed to site-specific evaluations of proposed facilities.

2. Evaluations are performed to identify information gaps, research needs, and needed regulations.

3. Resource and time constraints often limit the level of effort that can be devoted to the analysis of exposure levels.

4. Expected/allowable risk uncertainties are in the range of one to three orders of magnitude.

5. Because of the complexity of synfuels emissions, the risk analysis evaluates exposure and effects of categories of pollutants, as opposed to specific compounds. The use of representative compounds within each category (RAU) is the procedure, amenable to modeling, currently being utilized.

6. The characterization of expected emissions (i.e. the source term) involves significant uncertainties due to the lack of existing commercial scale synfuel facilities.

7. The exposure analysis is concerned with water-related migration and fate of contaminants contained in both potential point and nonpoint source discharges to waterbodies, and leachates generated by solid wastes and raw materials storage areas.

The second workshop focused on the terrestrial and aquatic food-chain models currently utilized in the process of risk assessment. To put these in perspective, Figure 3 is taken from the report by Breck and Bayes (REF). It presents the components of the human health risk assessment methodology for synfuels technologies and shows the relationships of the aquatic and terrestrial food-chain transport with the other major parts of the overall process. Thus, in moving from the synfuel pollution source to the assessment of health risk to man use is made of atmospheric and aquatic transport models, aquatic and terrestrial food-chain transport models, and models that estimate risks from calculated environmental exposures to synfuels chemicals (dose-response models).

Objectives of the workshop were to obtain the recommendations of experts on:

1. Terrestrial and aquatic food-chain models best suited to synfuels risk analysis.
2. Data sources and parameter estimation methods best suited to synfuels risk analysis.
3. Major limitations on existing data and methods.

Conclusions and major observations of the workshop participants would include the following:

1. A simple concentration factor approach is appropriate in aquatic food-chain modeling of chronic low-level releases of synfuels effluents.
2. In terrestrial food-chain models there is a need for greater model complexity to account for location-specific variations in agricultural practice (of course, concentration factors can be used to estimate terrestrial transport).
3. For aquatic and terrestrial models, field data are the best basis for estimating concentration factors. When field data aren't available, laboratory data can be used. If no data exist for a particular compound or class of compounds, estimates can be made using partition coefficients based on structure-activity relationships.
4. The need to estimate the uncertainty associated with particular model output.

5. The terrestrial food-chain model needs to include a consideration of a good contamination pathway via foliar absorption and translocation to edible produce parts.
6. The model should consider use of soil degradation kinetics which may be predicted from structure/activity relationships. These would be discerned from examination of the pesticide data base.
7. The model should consider using a prediction of the synfuel compound concentration in the soil solution. This would allow the prediction of the traditional soil/plant concentration factor from hydroponic data and provide a means for assessing the impact of synfuels compounds on crops.
8. A careful consideration of the effects of food processing (especially cooking) on human exposures should improve the model.
9. Consideration of several additional areas which need attention such as:
   a. inclusion of animal products other than beef and milk into the model
   b. accounting for differences in transfer coefficients resulting from livestock management practices
   c. water and soil ingestion by livestock (in addition to food)
   d. addition of irrigation water as a source term
   e. capability to model acute exposures and sensitive populations
   f. estimation of uncertainty associated with model predictions
10. Validation is the method not only to ensure that the assessment model is both appropriate and accurate but also to specify definitively the uncertainty associated with model predictions.

FIGURE 3

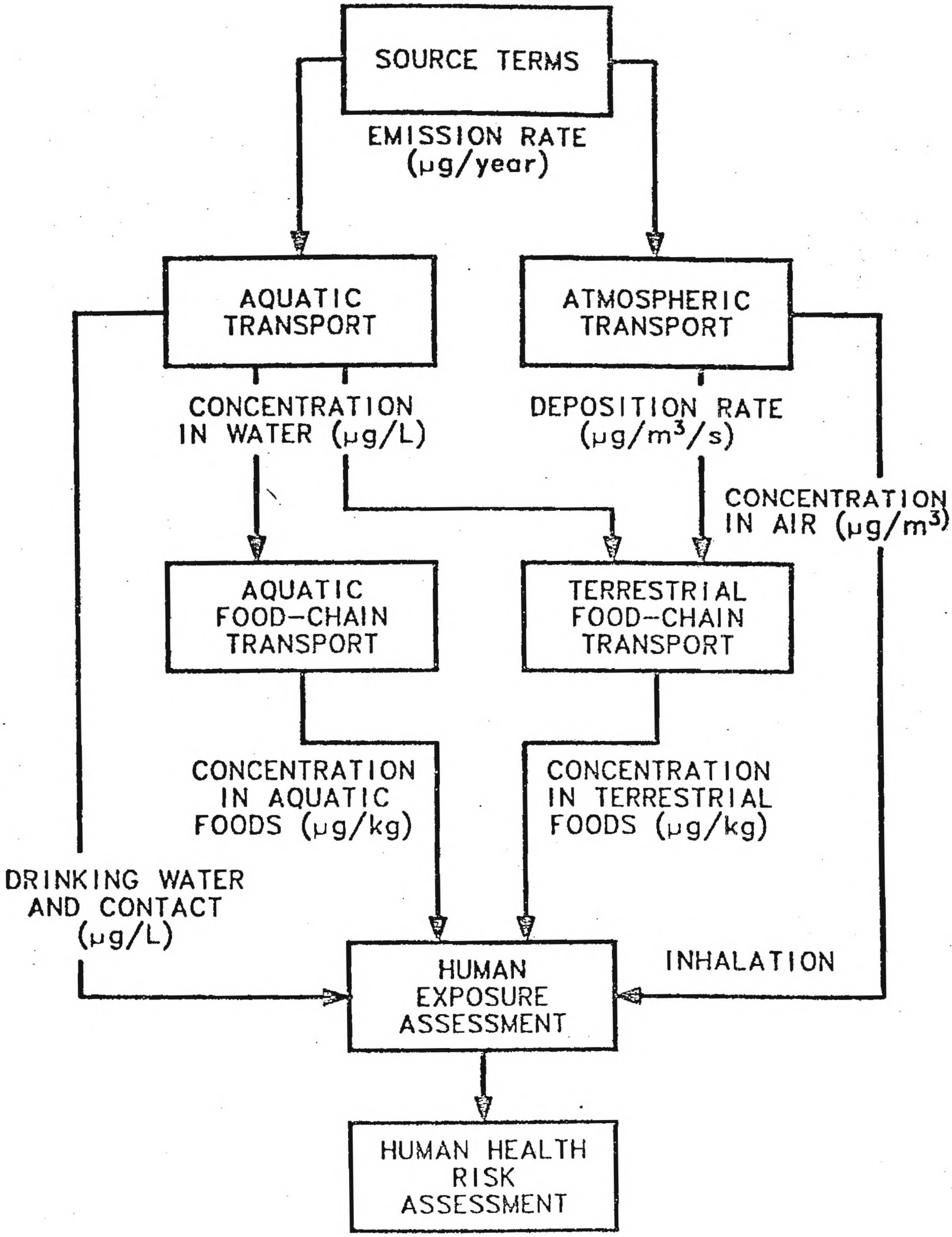

Fig. 1. Components of the overall human health risk assessment methodology for synfuels technologies.

XI. PEER REVIEW

The Peer Review process has been used extensively in the U.S. Environmental Protection Agency and is, in essence, an integral part of scientific research. The Integrated Health and Environmental Risk Analysis Program for Synfuels utilized this important process as an essential and continuing function of its research efforts. Not only was the overall Program reviewed periodically but also individual peer reviews were conducted on major program elements.

Peer Review Groups were established from time to time to review the entire program and were populated by outstanding experts in the field. Although members varied, there was always continuity represented by several individuals.

In an analogous manner, Peer Review Panels were formed to review major components of the Programs such as Health Effects, Food-Chain, etc. These Panels were usually smaller than the Peer Review Group and frequently had a member of the Group as a participant in its review and evaluation.

These Peer Review Groups and Panels usually met for one to two days and produced a draft report at the conclusion of each meeting. This was followed up by submission of a final report submitted by the Chairman to the EPA Project Officer on behalf of the members.

These meetings were preceded by the reading of pertinent reports and other written material. At the meetings, which were held at strategic locations, the Group or Panel was briefed by the individual researchers in accord with a predetermined agenda. There was discussion and interaction between researchers and Peer Reviewers. The procedure was then concluded by an executive session of the

Peer Reviewers in which a draft report was formulated for prompt delivery to the EPA Project Officer. This was promptly followed by submission of the final Peer Review report.

In addition to the Peer Review members and the pertinent researchers, these meetings were attended by EPA Program Officials, the EPA Project Officer, Users from relevant EPA organizational components, the Executive Director for Peer Review activities and small numbers of interested observers.

The Users are of special importance as these were representatives from the EPA offices which would be involved in establishing and implementing a regulatory program for synfuels technologies.

The schedule of the various Peer Review meetings and other relevant information are presented in Figure 3, whereas pertinent detail on the composition of the Peer Review members and their reports are included as Appendix ______.

This was an extremely important and useful procedure as it effectively helped guide the research and made numerous, beneficial suggestions and recommendations which were incorporated into the several scientific research efforts.

FIGURE 4

ENTIFICATION	CHAIRMAN	DATES	LOCATION
er Review Group	Dr. Norman C. Rasmussen	November 18-19, 1981	Knoxville, TN
er Review Panel n Human Health ffects	Dr. Arthur C. Upton	May 6, 1982	Brookhaven National Laboratory, Upton, NY
er Review Panel n the Food-Chain	Dr. Burton E. Vaughan	May 18, 1982	Comparative Animal Research Laboratory, Oak Ridge, TN
er Review Group	Dr. Stanley M. Greenfield	March 29-30, 1983	Alexandria, VA
er Review Panel n the Food-Chain	Dr. Melvin W. Carter, Executive Director	October 27-28, 1983	Environmental Research Laboratory, Corvallis, OR

E-25-K01

Georgia Institute of Technology

A UNIT OF THE UNIVERSITY SYSTEM OF GEORGIA
NUCLEAR ENGINEERING AND HEALTH PHYSICS PROGRAMS
SCHOOL OF MECHANICAL ENGINEERING

Please reply to:

NUCLEAR ENGINEERING AND
HEALTH PHYSICS PROGRAMS
CHERRY EMERSON BUILDING
GEORGIA INST. OF TECH.
ATLANTA, GEORGIA 30332 U.S.A.

November 10, 1986

Dr. Kenneth Hood
Project Officer
U.S. Environmental Protection Agency
Waterside Mall
Room 3821C, RD-682
401 M. Street, S.W.
Washington, D.C. 20460

Dear Dr. Hood:

In conformance with the requirements of our Cooperative Agreement, CR-812164-01-0, we are enclosing the original of the Final Report titled "Integrated Health and Environmental Risk Analysis Program for Synfuels".

Please let us know if the Report is approved and we shall distribute copies to the research groups involved in the research which is summarized in the Report.

Georgia Tech appreciates the opportunity to assist the U.S. Environmental Protection Agency in conducting meaningful research in support of its important mission.

Sincerely yours,

Melvin W. Carter
Neely Professor

MWC/bc
Enclosures

Telephone: 404-894-3720 Telex: 542507 GTRIOCAATL Fax: 404-894-3120 (Verify: 404-894-6951)

FINAL REPORT

INTEGRATED HEALTH AND ENVIRONMENTAL RISK ANALYSIS PROGRAM FOR SYNFUELS

FOR THE

OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY

NOVEMBER 10, 198~~1~~6

BY

MELVIN W. CARTER, Ph.D.
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WORK PERFORMED UNDER
COOPERATIVE AGREEMENT CR-812 164-01-0
U.S. ENVIRONMENTAL PROTECTION AGENCY

INTEGRATED HEALTH AND ENVIRONMENTAL RISK

ANALYSIS PROGRAM FOR SYNFUELS

LIST OF FIGURES

ABSTRACT

The Integrated Health and Environmental Risk Assessment Program for Synfuels was established by the Office of Research and Development, U.S. Environmental Protection Agency, for the purposes of developing and evaluating the health and environmental effects of synfuels technologies, evaluating the uses of synfuels, and providing a data base for use in a system of regulatory control and establishment of applicable standards.

The program sponsored and supported research and field investigations which produced valuable scientific input data and developed assessment methodology to evaluate the health and environmental effects of synfuels and the technologies used to produce them.

The research program included work performed by a number of EPA laboratories, academic institutes, several national laboratories, and private research organizations throughout the United States. One major field investigation was done in Yugoslavia as a cooperative effort with two U.S. Federal agencies, two U.S. National Laboratories and several industrial, governmental, and academic organizations in Yugoslavia.

Research results have been made available through technical presentations and reports, user's meetings, the peer review process, workshops, and user's manuals. In addition, a number of reports, supported by this project, are scheduled for publication in the near future.

A useful compilation of information and data on synfuels and synfuels technologies has been gathered; needed environmental and health data have been produced; and the assessment frameworks for environmental effects and for health effects have been developed for synfuels using concepts and procedures of risk analysis. This data base and these methodologies are documented and available for application if and when the United States decides to embark on the full-scale development and application of one or more synfuels technologies.

I. INTRODUCTION

Synthetic fuels usually are considered to include gaseous and liquid fuels as well as solid fuels which have been produced from the conversion of coal, oil shale, tar sands, and various forms of biomass. The conversion processes may be defined as synfuels technologies, and there are a number of these.

Among the reasons for using synfuels technologies are: the removal or conversion of nitrogen, sulfur, and other components which give rise to undesirable pollutants; the utilization of domestic energy resources and the achievement of independence from foreign sources; the replacement of unavailable, depleted, or more costly supplies of natural fuels; and the production of higher calorific fuels by the removal of unwanted constituents, such as ash, for more economical fuel handling and transport.

Some of the impetus for synfuels research in the United States was generated by the oil embargo of a few years ago and by a continuing increase in the costs of finding and producing new fossil fuel and other energy sources. It is also widely recognized that the world's supply of readily producible oil and natural gas is limited and will be exhausted in a matter of a few decades.

With increased demands for energy, it is prudent to secure alternative sources of energy along with the technologies necessary for their production and utilization. Energy conservation methods, while helpful, are not sufficient to achieve national goals of meeting energy requirements. In addition, a number of newer energy production technologies, such as solar and fusion, are long-range efforts with uncertain results.

Thus, for the decades immediately ahead, it appears that in addition to its sources of natural gas and oil the United States will be dependent primarily on coal, uranium, and perhaps oil shale.

During the recent decade of concern with energy sources there also has been a fundamental interest in and need to achieve and maintain basic environmental quality. The intense national mood and interest were codified in the passage of the National Environmental Policy Act of 1969 (NEPA63). In 1970 the U.S. Environmental Protection Agency and the Council on Environmental Quality were established.

Consequently, there has been a merging of two national concerns; namely the need to develop and produce alternate long-term energy sources and the need to make the technologies and fuel utilization processes as benign and innocuous to the public and the environment as possible. The constituencies and advocates for these two major national objectives are neither mutually exclusive nor completely compatible in all respects.

To some extent, the Energy Security Act of June 30, 1980 (ESA80) embodied each of these concerns (Di84). The Act created the U.S. Synthetic Fuels Corporation (SFC), defined its purpose, organization, financing, and responsibilities, outlined the environmental and health protection and monitoring requirements of each recipient of financial assistance from the SFC, and set production goals for industrial output of synthetic fuels.

Of particular interest here, in addition to the industrial stimulus it provided, are the definition of "synthetic fuels" and the requirements for environmental and health protection. According to the Energy Security Act, synthetic fuels are any solid, liquid, or gas produced from coal (including lignite and peat), shale, tar sands, certain categories of heavy oil, water for its hydrogen content, coal-oil mixtures, and magneto hydrodynamic topping cycles. The major environmental and health protection and monitoring provisions ensure that the supported projects will be consistent with protection of the environment and environmentally acceptable, have a high potential to meet regulatory requirements, and present a plan for monitoring environmental-and health-related emissions.

Several Congressional Committees, such as the House Committee on Science and Technology and its Subcommittee on Energy Research and Production, have expressed the view that environmental, health, and safety research is the key to the prospects for developing and building environmentally acceptable synthetic fuel plants (Du84). These committees, of course, are supply oriented with emphases on national security, energy, and technology rather than on environment, health, safety and protection.

Individuals with industry, such as G.K. Vick of Exxon Research and Engineering Company (Vi84), have also stated their views regarding the need for safety and protection as an inherent part of industrial synfuels technology development. The developed technologies need to be safe to workers, customers, the environment, and the general public as well as acceptable to the customers and the public.

Because the U.S. Environmental Protection Agency put into place a comprehensive program of research and development to produce needed information and data for the development of regulatory standards for synfuels technologies and the use of their products, the environmental and health protection programs are being developed on a concurrent basis with synfuels technologies.

A major component in the Environmental Protection Agency effort was the establishment of the Integrated Health and Environmental Risk Analysis Program for Synfuels, set up under the aegis of the Office of Research and Development. This program supported basic research to obtain data needed for the uptake of synfuels chemicals by various environmental media and for biological data regarding the effects of synfuels chemicals on human populations. These experimental research programs provided some of the needed input into environmental effects models as well as health effects models.

Another major attribute was the close and effective coordination established between the Integrated Health and Environmental Risk Analysis Program for Synfuels in the EPA with its counterpart organization in the U.S. Department of Energy, the Health and Environmental Risk Analysis Program. There were close personal relationships between the respective project officers and their staffs and among the several research groups involved with the various research efforts. Such activities were most useful and added greatly to the efficient production of research results while avoiding duplication.

This positive climate for synfuels work and research, including health and environmental effects studies, has, of course, changed over the years. In fact, the trend has been to reduce support and thus curtail technology and research efforts.

II. ENERGY TECHNOLOGIES TO PRODUCE SYNFUELS

Synthetic fuels are produced in a number of countries to help them meet energy requirements. However, in the United States there has been little emphasis placed on the need to develop synfuel technologies. In this section we shall briefly review synfuels technologies and the possible production of synfuels for use. The establishment of the SFC added emphasis to these efforts within the United States.

The basis for synfuels technologies is the conversion of carbonaceous materials to synthetic fuels through the process of hydrogenation. Thus, our common fuels such as natural gas and gasoline have a higher hydrogen content than the raw materials considered as resources for conversion. These include coal, oil shale, tar sands, and several forms of biomass.

In the hydrogenation processes water is the source of hydrogen. Therefore, the synfuel technologies are intended to decrease the carbon to hydrogen ratio in the conversion process. For example, on a mass basis the ratio of carbon to hydrogen varies from about 15 for bituminous coal, approximately 9 for crude oil, to 6 and 3, respectively, for gasoline and methane. Oil shale and tar sands are close to crude oil in carbon to hydrogen ratio and are thus more amenable to synfuel technology than coal.

An environmental concern is the amount of mineral material contained in the energy resource. If the content is high, large quantities of material must be mined and handled and the resulting large volumes of solid waste must be disposed of in an acceptable manner.

The hydrogenation process may be direct, indirect, or by pyrolysis, either alone or in combination. In the direct process, hydrogen at high pressure is used, whereas steam is used in the indirect process. The pyrolysis process involves heating the raw hydrocarbon source until it thermally decomposes into its several products.

In the book, "Synthetic Fuels" (Pr82), the various conversion processes are defined and described in detail. The process selected is usually based on a variety of chemical and physical properties of the raw fuel and these properties and the conversion process characterize the products which are generated.

There is a variety of types of coal in the United States whereas there are two principal types of oil shale, namely that from the Green River Formation and black shale. The oil shales contain "kerogen" which is not a member of the petroleum family but contains a high-molar-mass organic material. The major part of the oil derived from "kerogen" is obtained from pyrolysis.

Tar sands contain a high-viscosity crude hydrocarbon in the form of bitumen which is a member of the petroleum family. The United States is not a major source of tar sands, but extensive deposits have been identified in Canada.

Various forms of biomass can be converted to synthetic fuels and the production of alcohol from the fermentation of grain is a good example. However, in the United States, grain is looked upon more favorably as a food stuff than as an energy source. Wood is a biomass energy resource, but it is not known whether or not it can be used on an economic basis.

Approximately 80 percent of the world's supply of non-renewable energy resources is in the form of coal. Thus, the United States, with about 25 percent of the world's coal reserves, is in a most favorable position.

In applying various synfuels technologies to the conversion of coal to synfuels, the thermal efficiencies are about 40-50, 60-65, 65-70, and 70-75 percent for indirect liquefaction, gasification, direct liquefaction, and solvent refining, respectively.

Oil shale is found nonuniformly in the world with approximately two-thirds identified in the United States. Of the remainder, Brazil has about one-quarter with smaller quantities found in several other countries. It is not certain how effectively and efficiently synfuels can be produced from these identified resources of oil shale.

Tar sands are found in various countries in the world with major resources found in Canada, Venezuela, and the U.S.S.R. The United States has relatively minor quantities located almost exclusively in Utah. Unless newer and more efficient conversion processes are found, the U.S. resources will not support other than relatively small production efforts.

Thus far, there are no full-scale synfuels plants in operation in the United States. However, there are plants operating in various other countries, and some have been in operation for a number of years.

The United States does have several pilot plants in operation or in advanced preparation for operation. This is important experimentally in that actual samples of effluent and other source terms can be obtained for use.

If health and environmental protection research can continue on a concurrent basis with engineering development of synfuels technologies, these efforts will come to fruition in time to guide decisions regarding full-scale production methods and priorities. Results of such efforts can help provide guidance in control technology, avoidance of accidents, remedial actions to spills and other contaminating events, and appropriate modification of the process and the product.

As summarized by Gray and Drucker (Gr81), various epidemiological studies and toxicological research on several synfuels conversion processes have suggested that the products may have carcinogenic properties as well as greater acute and chronic toxicity when released to the environment as compared to crude petroleums.

As with any new technology, it behooves us to fully evaluate synfuels technologies before they are extensively used in the United States. We must understand their nature and characteristics and develop the appropriate data base to document their health and environmental effects and thus undergird the development of regulatory standards and strategies.

Risk analysis is a useful tool in this effort and can be used to predict the frequency, characteristics, and severity of health and environmental consequences.

An initial step in the process of assessment (risk analysis) is the identification and quantification of the possible source terms from the various synfuel technologies as well as from the handling and use of the synfuels. Information and data in this regard are contained in a series of four reports produced by TRW Energy Technology Division (TRW83a, TRW83b, TRW83c, TRW83d).

Three of the reports provide estimates of source terms for liquid synthetic fuel technologies; whereas the fourth contains an analysis of the various aspects associated with utilization of synfuel products. Results are given in terms of Risk Assessment Units (RAU) (Mo82)[1]. In the three conversion process reports (TRW83b, TRW83c, TRW83d), the technologies are described and eight processes are discussed. For example, in the direct coal liquefaction process, H-coal, SRC-I, SRC-II, and the Exxon Donor Solvent methods are covered; in the indirect coal liquefication process, Fischer-Tropsch synthesis via Lurgi and Koppers-Totzek gasification methods are presented; and the TOSCO II and Paraho processes are contained in the report on oil shale extraction.

The fourth report, "Source Term Estimates for Synthetic Fuels Technologies Analysis of Product Utilization"(TRW83a), characterizes the products produced by the eight synthetic fuels processes described in the companion reports, discusses the likely mode of transportation, and describes the end uses of each product.

1 This Unit will be defined and discussed in Section III of this Report.

III. ASSESSMENT OF SYNFUELS TECHNOLOGIES

The assessment of synfuels technologies is complex due to the multitude of potential effluents and their chemical and physical forms, the various media these are in, the effects of process parameters, and the uncertainty as to which technology may reach commercial scale and begin production. Thus, the approach has been to examine all feasible technologies as their development progresses.

Our interest is assessment of the health and environmental effects of the synfuels technologies as they relate to the workers in the conversion process and to the public and the environment due to potential impacts resulting from the synfuels technology or the use of synfuels. This is a broad scope, but it is critical in establishing pertinent regulatory standards and controls.

In order to deal with the multitude of chemicals involved in the effluents and products of synfuels technologies, the approach was taken to group these in categories which were designated as Risk Assessment Units (Mo82). The procedure would then be to select one or more representative chemical components from an RAU for studies of effects. This process would then make the system manageable and allow progress to be made in the research and development in a reasonable time frame.

The RAU's were designated based primarily on their chemical characteristics. Other factors could be used, such as technology production parameters or health and environmental effects. The list of RAU's is shown in Figure 1 and had 38 categories.

FIGURE 1
RISK ASSESSMENT UNITS/CATEGORIES

NUMBER	CATEGORY	DESCRIPTION
1	Carbon Monoxide	CO
2	Sulfur oxides	SOx
3	Nitrogen oxides	NOx
4	Acid gases	H_2S, HCN
5	Alkaline gases	NH_3
6	Hydrocarbon gases	Methane through butanes, acetylene, ethene through butenes; C_1-C_4 alkanes, alkenes, alkynes and cyclo compounds; bp<~20° C
7	Formaldehyde	CHO
8	Volatile organochlorines	To bp~120° C; CH_2Cl_2, $CHCl_3$, CCl_4
9	Volatile carboxylic acids	To bp~120° C; Formic and acetic acids only
10	Volatile O&S heterocyclics	To bp~120° C; Furan, THF, thiophene
11	Volatile N heterocyclics	To bp~120° C; pyridine, piperidine, pyrrolidine, alkyl pridines
12	Benzene	Benzene
13	Aliphatic/alicyclic hydrocarbons	C_5 (bp ~ 40° C) and greater; paraffins, olefins, cyclocompounds, terpenoids, waxes, hydroaromatics
14	Mono/Diaromatic hydro-carbons (excluding benzene)	Toluene, xylenes, naphtahlenes, biphenyls, alkyl derivates
15	Polycyclic aromatic hydrocarbons	Three rings and greater; anthracene, BaA, BaP, alkyl derivatives
16	Aliphatic amines (excluding N-hetero-cyclics)	Primary, secondary and tertiary nonheterocyclic nitrogen, $MeNH_2$, DiMeNH, TriMeN
17	Aromatic amines (excluding N-hetero-cyclics)	Anilines, naphthylamines, amino pyrenes; nonheterocyclic nitrogen

18	Alkaline nitrogen heterocyclics ["aza-arebes"] (excluding "volatiles")	Quinolines, acridines, benzacridines; excluding pyridines
19	Neutral N, O, S hetero-cyclics (excluding "volatiles")	Indoles, carbazoles, benzofurans, dibenzothiophenes
20	Carboxylic acids (ex-cluding "volatiles")	Butyric, benzoic, phthalic, stearic
21	Phenols	Phenol, cresols, catechol, resorcinol
22	Aldehydes and ketones ["carbonyls"] (excluding formaldehyde)	Acetaldehyde, acrolein, acetone, benzaldehyde
23	Nonheterocyclic organo sulfur	Mercaptans, sulfides, disulfides, thiophenols, CS_2
24	Alcohols	Methanol, ethanol
25	Nitroaromatics	Nitrobenzenes, nitropyrenes
26	Esters	Acetates, phthalates, formates
27	Amides	Acetamide, formamide, benzamides
28	Nitriles	Acrylonitrile, acetonitrile
29	Tars	
30	Respirable particles	
31	Arsenic	As, all forms
32	Mercury	Hg, all forms
33	Nickel	Ni, all forms
34	Cadmium	Cd, all forms
35	Lead	Pb, all forms
36	Other trace elements	
37	Radioactive materials	Ra-226
38	Other remaining mate-rials	

The work on the RAU concept and its development was done by a group of researchers in the field during 1981 with the final list completed early in 1982. During 1982 the decision was made to replace Unit with Category which was a more definitive and meaningful term.

This concept proved very useful. It permitted a rational grouping of the myriad of chemical compounds potentially produced and emitted from a synfuel site. Thus, it provided common analysis categories for the assessment of health and environmental effects.

The RAU/RAC concept was reviewed by a Peer Review Group in early 1983 and one of its comments is paraphrased below:

> The RAU concept adopted for health and environmental assessments seems to be a workable compromise between the overwhelming problem of dealing with a large number of chemicals on a case-by-case basis and the intractable problems associated with risk assessment of complex mixtures. The approach has certain limitations, e.g. the toxicity of an RAU category for one industry may be quite different than that of the same category for another industry, but these difficulties seem surmountable if rigid estimates of RAU toxicity are avoided. The rationale provided for use of RAU's was straightforward and reasonable, chemical categorization must be compatible with analytic methods, and categories should be mutually exclusive and collectively exhaustive.

The work on RAU/RAC was done under the direction of the Integrated Health and Environmental Risk Analysis Program (IHERAP) of the Office of Research and Development (EPA). Its functions were reorganized and work was launched early in 1981. Research was performed both at EPA facilities and under contract with appropriate outside organizations. Major groups involved with this work are:

Industrial Environmental Research Laboratory - Research Triangle Park, North Carolina

Environmental Research Laboratory - Corvallis, Oregon

Environmental Research Laboratory - Duluth, Minnesota

Environmental Research Laboratory - Athens, Georgia

Brookhaven National Laboratory - Upton, New York

Oak Ridge National Laboratory - Oak Ridge, Tennessee

Los Alamos National Laboratory - Los Alamos, New Mexico

Comparative Animal Research Laboratory - Oak Ridge, Tennessee

University of Wyoming - Laramie, Wyoming

Georgia Institute of Technology - Atlanta, Georgia

Tennessee Valley Authority - Chattanooga, Tennessee

There were also other major interests and programs in synfuels technologies and their health and environmental effects. These were undertaken by the:

U.S. Department of Energy

National Institute of Occupational Safety and Health

U.S. Synthetic Fuels Corporation

Mechanisms to provide effective coordination and cooperation in appropriate common areas of work were established early in the program effort. There were frequent contacts and meetings amongst researchers as well as exchanges of correspondence and reports, liaison meetings, and joint research conferences. In most cases, representatives of the Federal agencies participated in each others meetings in synfuels related work.

A chronology of major events in the history of the Integrated Health and Environmental Risk Analysis Program for Synfuels is presented as Figure 2. It includes important events in the management and direction of the program and covers such things as Peer Review Group meetings, User Review Meetings and Workshops. Details of these events are contained in the project files and/or reports published in the scientific literature.

Work was needed to identify potential health and environmental adverse effects, quantify the nature and characteristics of these effects, transform these quantitative estimates of hazards into estimates of risks to man and the environment, and develop effective regulatory standards and control procedures.

Work on synfuels technologies from the engineering viewpoint and in atmospheric effluents was centered at the Industrial Environmental Research Laboratory, Research Triangle Park. The Tennessee Valley Authority also had a roll in the area of synfuels technology due to their work in energy production.

The occupational health and safety aspects of the program were a cooperative effort by Brookhaven National Laboratory and Los Alamos National Laboratory.

FIGURE 2

INTEGRATED HEALTH AND ENVIRONMENTAL RISK ANALYSIS PROGRAM
CHRONOLOGY OF EVENTS

TIME FRAME	EVENT	PLACE
November 17-18, 1980	Scoping Meeting	Oak Ridge, TN
March 3, 1981	Reorientation Memo	Washington, D.C.
April 21-22, 1981	Dixon Committee Meeting	Oak Ridge, TN
July 21-22, 1981	Categorization of Chemical Compounds Associated With Synthetic Fuels Technologies for Risk Assessment	Alexandria, VA
August 17-18, 1981	Combustion Product Evaluation	Alexandria, VA
October 5, 1981	Preliminary Report on RAUs	Oak Ridge, TN
November 4-5, 1981	User Review Group	Washington, D.C.
November 18-19, 1981	Peer Review Group	Knoxville, TN
January 25, 1982	"Final" List of RAUs	Washington, D.C.
May 6, 1982	Peer Review Panel (Health Effects)	Upton, NY
May 18, 1982	Peer Review Panel (Food Chain)	Oak Ridge, TN
September 23-24, 1982	User Review Group	Washington, D.C.
January 18-20, 1983	Workshop on Water Modeling	Atlanta, GA
March 22-24, 1983	Workshop on Food Chain Modeling	Washington, D.C.
March 29-30, 1983	Peer Review Group	Alexandria, VA
October 27-28, 1983	Peer Review Panel (Food Chain)	Corvallis, OR
December 14-16, 1983	User Review Group	Washington, D.C.
May 5, 1984	Program Suspended	Washington, D.C.
November 9, 1984	Peer Review Panel (Kosovo Study)	Upton, NY

Epidemiology and medical effects evaluation of the synfuels technologies were performed at Brookhaven National Laboratory as was the risk analysis for health effects.

The environmental assessments and environmental transport and fate models were a function of Oak Ridge National Laboratory as was the risk analysis for environmental effects.

Food chain models were developed and implemented at ORNL. Research to develop necessary parameters and data for the models was done at three laboratories, considering both the needs of the food chain models and the priorities established by the health effects groups.

Studies on uptake, distribution, and retention of selected RAC chemicals by cows, swine, and poultry were done at the Comparative Animal Research Laboratory in Oak Ridge. The plant uptake, distribution, and retention studies of a terrestrial nature were done at the Environmental Research Laboratory, Corvallis, whereas the work related to aquatic species was performed at the University of Wyoming and at the Environmental Research Laboratory, Duluth.

The Environmental Research Laboratory, Athens, was involved with the water pathway and especially work on the modeling of synfuels chemicals.

Certain management functions including responsibility for Workshops and the Peer Review Process were located at the Georgia Institute of Technology.

IV. OCCUPATIONAL HEALTH ASSESSMENT

Due to the lack of large-scale operational synfuels plants in the United States it was necessary to utilize other types of facilities, with some comparable characteristics, to study the occupational health aspects of synfuels technologies. The other approach was to identify and use a large-scale, commercial synfuels plant located in another country. Both approaches were instituted and are represented by studies on coke-oven workers and workers at the coal gasification plant in Oblic, Yugoslavia, Autonomous Province of Kosovo, which is operated by Elektroprivreda Kosovo.

The purpose of these studies was to relate occupational exposures of workers to synfuels chemicals (or comparable industrial chemicals) to various health parameters which may be identified and measured. Thus, the coke-oven worker population was to serve as a surrogate population for an actual worker population engaged in a synfuels technology.

COKE-OVEN WORKERS

The rationale for selecting the Pittsburgh coke-oven workers for study (surrogate group) was the similarity between the exposures to toxic substances in coal hydrogenation technology and coal conversion to coke. Also, there is a large amount of epidemiologic data available on the coke-oven population, and it demonstrates the risk of respiratory and genitourinary malignant disease is significantly increased.

A fundamental reason for a study of the coke-oven workers was to demonstrate the usefulness of a unique approach to health and environmental risk analysis. Thus, while the synfuel industry is being developed on a small-scale basis, the analysis of its technology, products, and waste streams as to their health and environmental effects should provide a solid basis for environmentally sound practices in technology development.

Concurrent with the study of coke-oven workers, there were plans being made to conduct a large-scale epidemiological study of coal gasification workers in Yugoslavia. The coke-oven worker study would thus serve as a small-scale pilot study in which to use, evaluate, and modify the proposed clinical measure's methodology of the Yugoslav project.

The four objectives of the pilot study are taken from an unpublished report "Coke-Oven Workers Study" (Mi84).

1. To evaluate the epidemiological and clinical methodologies to be used in the Yugoslav project.
2. To identify, if possible, potential occupationally-related morbidity effects.
3. To provide information to be used in the Integrated Health Risk Analysis Program based on human exposure to chemicals that represent risk assessment factors or are surrogates for Risk Assessment Categories (RAU's).
4. To provide data on the upper levels of health impact of synfuels related production and processes for input into an Integrated

Health Risk Analysis. These data relate work site exposures to relevant pollutants and toxicants to the health status of workers and neighboring populations.

The initial plan was to evaluate coke-oven workers with 20 years employment in the same plant and with a minimum of five years "topside" exposure, and control subjects, matched by age, sex, race and cigarette smoking history, employed for 20 years in the same plant, but never as cokers, i.e. non-exposed.

Planning also called for the transport of the members of the study population to the Medical Research Center at Brookhaven National Laboratory for three days of medical evaluation including standard clinical tests plus more recently developed test procedures. These new procedures included cytogenetics (chromosomal aberrations and sister chromatid exchange), *in vitro* cultures of hematopoietic percursor cells (CFU_c, BFU_e, CFU_e), ventilation - perfusion lung scans, and benz-a-pyrene DNA adducts measured in peripheral blood cells. Each person would also have a complete occupational chemical exposure profile determined.

The report (Mi84) presents in detail the rationale and objectives of the Pittsburgh coke-oven worker study, the selection of workers, clinical health assessment procedures, and exposure assessment procedures. The report also compares the actual study outcomes to the expected outcomes and discusses lessons learned from the actual processes. These lessons are then to be applied to the final designs of the Yugoslav study as well as any future planned, similar U.S. studies. Finally, the text concludes with descriptions of the study findings and recommendations.

Several very important lessons were learned from this study. There was a severe selection bias of both workers and controls due to a variety of reasons. These included the effects of a recent strike, financial loss to take the several days needed to participate in the study, and the inconvenience of traveling to New York for the clinical evaluation. These and other causes also minimized the number of workers willing to participate.

It was also difficult to obtain any meaningful exposure data on workers. Causes included many uncertainties in obtaining occupational histories, lack of information on specific exposure histories, and the inability to make arrangements for the collection of pertinent samples in the work place.

Also complicating this situation is the meager amount of information in the literature on exposures of workers to specific chemicals. Exposure data are generally available as a coal tar pitch volatile measurement which is a nonspecific analytical procedure for monitoring benzene or cyclohexane soluble compounds and thus not very useful for addressing exposures in terms of specific chemical species (RAU's). Thus, it was not possible to develop useful exposure profiles for the individuals studied, except for coal tar pitch volatiles.

A large amount of time, over an extended period, was devoted to negotiations with industry management and union representatives. Also, industry management, although willing to comply with the law or union contract clauses in the release of information, would not release information which may be detrimental to future negotiating positions or which may indicate over exposures to future occupational health standards. The lesson is that future U.S. studies must identify other mechanisms to obtain the understanding and cooperation among the workers that the benefits of participation in health effects studies are important to the worker, his family and his co-workers.

These lessons learned were carefully reviewed as to guidance for the Yugoslav study. Many factors involved are different between the two sites. In Kosovo there would be complete and full participation by management and the workers and, thus, no self-selection bias. Work dossiers, containing a record of all lifetime employment, are maintained for each worker. A clinic and a laboratory are fully staffed and available for worker medical examinations as well as specimen collection and analysis. Also, at the Kosovo Plant, exposure data were obtained by actual industrial hygiene sampling measurements.

Conclusions for the Coke Oven Workers Study, in addition to those summarized as lessons learned, are given below (Mi84):

> Complete cooperation by workers and management is necessary for the success of any in-depth health assessment evaluation of workers for morbidity. The health evaluation and occupational history exposure questionnaires were satisfactorily validated. Information was obtained on several new experimental clinical evaluation test procedures as predictors of disease. New information was obtained and understanding improved regarding basic mechanisms and

synergistic effects that coke-oven emissions (complex mixtures) have on human health. Epidemiologic study methodologies, full-scale retrospective and prospective, were substantiated.

KOSOVO COAL GASIFICATION PLANT WORKERS

The Kosovo coal gasification plant was selected for study because it was readily available for study and was a large-scale operating facility which has been in use since 1973. It employs Lurgi East German technology and design and produces medium BTU commercial gas as well as several other products.

The research study was a joint cooperative effort of the U.S. Environmental Protection Agency, the U.S. Department of Energy, and the National Institute of Occupational Safety and Health in the United States and various groups in Yugoslavia. These include the Institute Kosovo, University of Kosovo (formerly University of Pristine), Institute for Application of Nuclear Energy to Forestry, Veterinary Medicine and Agriculture, Institute for Medical Research and Occupational Health, and the cooperation and assistance of Elektroprivreda Kosovo which operates the coal gasification plant in Oblic (outside Pristina) in the Autonomous Province of Kosovo.

United States interest in the study of this Yugoslav synfuels plant center on three areas:

1. An occupational health study of workers in an actual operational facility before one is placed in operation in the United States.

2. Possible generic use of the results in the continuing health and environmental evaluation of synfuels technologies.

3. A long-range interest in continuing the policy of cooperative scientific exchanges with Yugoslavia.

Of course, it is well recognized that the Kosovo plant is of an old design and has limited pollution and occupational health engineering control features. However, results could represent a "worse case" exposure situation which could provide valuable information for use as guidance in the design, construction, and operation of coal gasification plants in the United States.

The coal gasification plant is operated as part of a large industrial complex. The gas produced is used partly for fuel and partly for fractionation; that is, for the recovery of hydrogen which is further used for ammonia synthesis. The fraction of gas after hydrogen recovery is enriched with methane which is mixed with the remainder of pure gas.

Major components of the coal gasification plant are:

1. Six generator units.
2. A condensation plant.
3. A rectisol plant for purification of raw gas.
4. An air separation plant (oxygen and nitrogen are produced).
5. A tar and medium oil separation plant.
6. A phenol separation plant.
7. A plant for biological treatment of waste waters (not operated).

The coal for the conversion process is obtained from two strip mines located nearby. These mines produce lignite coal which is pulverized and dried by the Fleisner drying procedure before use in combination with oxygen and superheated steam at a pressure of 23 bars and a temperature of 350^{o}C.

Previous cooperative work with the Kosovo facility has been done for several years by Radian Corporation and various Yugoslav institutions and supported by the EPA's Industrial Environmental Research Laboratory - Research Triangle Park, NC. Much of this effort was to characterize process streams and fugitive emissions at the gasification plant.

The basic purpose of the study was to conduct an occupational health assessment of workers engaged in a coal gasification facility as one of the synfuel technologies. It would thus provide an opportunity: to assess the impact of a coal gasification facility on the health of its workers and the community adjacent to the facility; to evaluate the feasibility and acceptability of present safety and health standards for the protection of workers and the applicability of work practices and control procedures; and to obtain needed information and data well in advance of large-scale synfuels technology development in the United States.

Initial efforts by the Yugoslavs were initiated in 1980 to evaluate the health consequences that the coal gasification imposed on the workers and the local, general population. In 1983, a second phase joint cooperative effort to be conducted by investigators from the United States and

Yugoslavia was negotiated. It was to be a comprehensive health effect study consisting of industrial hygiene (exposure), epidemiological, and clinical components.

The industrial hygiene program was designed to: characterize the chemical and physical stresses in the workplace; investigate the use and effectiveness of engineering control systems, and employee and administrative work practices; evaluate plant and comparitive population exposures; conduct special studies to assist the clinical and epidemiology programs; develop information and technology transfer between United States and Yugoslav coal gasification plants; initiate technology transfer to Yugoslavs for subsequent routine monitoring; and to accomplish communication, liaison, and logistic activities with the Yugoslavs as needed (Ja84a).

The purpose of the investigations of the health effects from exposure was to evaluate the potential impact of the plants' operation on the workers and the general public (Mor85d). Effects of exposure to various chemicals in the working environment will be studied in detail in the exposed and control workers. Detailed assessments of the effects on people working in the generator plant, phenolsolvan plant, and rectisol plant will be made. Similar procedures will be employed to any population exposed to various contaminants. The industrial hygiene studies, carried out concurrently with the clinical and epidemiological investigations, will allow the establishment of a cause/effect relationship between the presence of chemical substances and health impairments, if such are observed.

Progress and the status of these research efforts are discussed in a report by Morris (Mor85a). He also discusses the background of this cooperative work, including the agencies and groups involved and the specific responsibilities of individual organizations. According to Morris, the responsibility for industrial hygiene and exposure monitoring were split among BNL, LANL, and the NIOSH Morgantown, WV, laboratory whereas the BNL had responsibility for health effects and epidemiology.

The protocol for the July, 1984 characterization campaign (Ja84a) and the strategy for the industrial hygiene personnel sampling campaign scheduled to begin in March, 1985 (Ja84b) were developed by the cooperative work of BNL, LANL, and NIOSH groups.

Detailed plans for the research on health effects and epidemiology were prepared by the BNL (Mor84a). Early efforts in these areas address respiratory illnesses and skin cancer.

Essentially all these efforts were cooperative ventures between Yugoslav and American scientists and support personnel. The expertise of each country was used effectively.

These studies are continuing although certain preliminary results and conclusions have begun to appear. For example, an entire session of "The 1985 American Industrial Hygiene Conference" in Las Vegas, NV in May, 1985 was devoted to the title "Occupational Health Study of the Kosovo, Yugoslavia, Coal Gasification Plant" (AIHC85). Papers ranged from an overview of the study and a discussion of the Lurgi process at Kosovo to the details and results from the industrial hygiene, clinical, and epidemiological studies. The authors of these papers were from Yugoslavia and the United States.

Results of the 1981-82 Yugoslav conducted sampling, the 1984 joint United States/Yugoslav area sampling campaign, and the 1985 joint personnel sampling campaign all show that worker exposures to a wide variety of coal gasification airborne workplace contaminants are usually below occupational exposure limits (such as those of the American Conference of Governmental Industrial Hygienists). On the other hand, acute exposure to such contaminants as CO and H_2S can occur due to process leaks. These observations must be tempered in view of the fact that engineering control of airborne contaminants is not as extensive at Kosovo as would be found in the United States and that maintenance and upset event exposures were not included (Ja86a, Ja86b). The latter report, Ja86b, is a draft report on the Industrial Hygiene Program as a part of the overall report on the Kosovo studies.

V. SUPPORTING ACTIVITIES

To evaluate the exposures and effects of synfuels chemicals on health and the environment, it is necessary to determine the extent to which these materials are taken up and retained in the food chain. For practical purposes the food chain is divided into two major categories, namely terrestrial and aquatic. In addition, the terrestrial category may be conveniently subdivided into plants used for food and food-producing animals.

ANIMAL RESEARCH

The work on food-producing animals was performed by the Comparative Animal Research Laboratory (Oak Ridge Associated Universities) in Oak Ridge, TN. This was an experimental effort to determine and evaluate the significance of food chain contamination from synfuels technologies by studying the ingestion, metabolism and retention of synfuels chemicals in chickens, pigs, and cows.

The goal was to develop data for use in the food chain analysis of synfuels-related chemicals by determining the uptake and biological retention of RAU/RAC compounds in food-producing animals (dairy cattle, swine, and poultry) and obtaining the transfer coefficients required for food chain exposure assessments. These species of animals are widely used by humans for supplies of meat, milk and eggs.

Specific goals of the project were to:(Ei82)

1. Determine the biological retention of representative compounds following acute and chronic oral administration to food-producing

animals; determine the accumulation and loss of these compounds in consumable products following an acute dose; and determine the rate of accumulation in tissues when they are administered chronically.

2. Determine and employ practical methodology for the isolation and quantitation of selected compounds that are representative of the major chemical classes found in synfuels products and waste materials.

This laboratory was also involved in the early research of plant uptake of synfuels chemicals. The goal of this phase of the work was to determine the extent of uptake, transport, and concentration of representative compounds in selected vegetable crop species commonly used by man as foods. Included within the test plant selection was broad physiological and morphological diversity with reference to the plant organ used for human consumption (Sc82).

The report by Schwarz and Eisele (Sc82) represents a good summary of the rationale for the research materials selected for study, procedures used in both acute and chronic studies, sampling, analysis, and radiometric methods, species of animals utilized in the experiments, and certain results obtained for several RAU compounds.

Data for studies of naphthalene (RAU#14), naphthol (RAU#21), and 7-methylbenz (c) acridine (RAU#18) indicate that all three compounds are transferred to and found in various animal products, i.e. milk, eggs, and meat. Thus, for these chemicals there is a potential risk from the food chain. Similar results were obtained for studies of BaP (RAU#15) in chickens and pigs.

Early research work by this group using a hydroponic experimental system demonstrated that pea, onion, and lettuce plants took up naphthalene, naphthol, and 7-methylbenz (c) acridine and that the parent compound or its metabolites reached the edible portion of the plant in a relatively short time.

Other results from this group have been reported in the literature (Ei85a, Ei85b, Ei86). These data cover work on other synfuels chemicals, such as aniline (RAU#17) and indole (RAU#19), as well as additional information on the total program and its results. These other synfuels, when used in feeding experiments, demonstrate an accumulation and retention of them or their metabolites in consumable meats, eggs, and milk. Of course, in all the synfuels feeding experiments performed there is a difference in species and in tissue distribution and concentration. This suggests that exposures would depend upon the quantity of contaminated food consumed as well as the specific product involved.

The capability of biomagnification may allow an animal to accumulate relatively small quantities of chemicals into levels that are considerably in excess of that encountered in the environment. Since almost the entire animal is ulitized either directly (consumable products) or indirectly (animal feed additives, etc.), and with many animal products subsequently being recycled into alternate food products (dried eggs in baking products, etc.) which have a long consumer shelf life, the possibility of prolonged exposures of humans to low levels of chemicals must be recognized.

TERRESTRIAL PLANT RESEARCH

The terrestrial plant research was conducted at the Environmental Research Laboratory, Corvallis, OR. The overall goal of the plant research program was to obtain an understanding of the mechanisms of xenobiotic chemical uptake, translocation, accumulation, and metabolism in plants. This knowledge was then applied to the various chemicals associated with the several synfuels technologies. Models were developed which coupled the plant data with the movement of water, photosynthates, and mineral nutrients to predict vegetational bioaccumulation and food contamination and thus a portion of the environmental fate of toxic chemicals (Bo85).

An EPA report (McF86), "Plant Exposure Laboratory and Chambers" presents details on the design, construction, and operation of the laboratory and the exposure chambers. The objective was to be able to do plant uptake studies in a manner in which toxic and radio-labeled chemicals could be contained and controlled in an environment where plant physiological parameters can be observed and positively managed. This report also contains appendices which address the computer programs devised to manage the equipment and data from the exposure laboratory; the source code and description used for the control program; details of the construction drawings and parts list pertaining to the plant exposure chamber; the diagrams for electronic components of the laboratory; details of the construction and calibration of the thermistor used for temperature regulation; and the construction of the hydroponic plant nursery as well as the recipes for several nutrient solutions. Other computer management and calculational programs were developed to assist in the accomplishment of the experimental work.

Initial screening work was done using excised roots of barley plants to learn the uptake characteristics of toxic organic chemicals. A number of papers describe the experimental procedures (Wi85a, Wi85b) and the results obtained with a number of synfuels chemicals (McF85a, Wi83, Wi84). The paper by McFarlane and Wickliff (McF85a) is a summary of their work in using excised barley roots for uptake studies of several organic chemicals labeled with carbon-14. Chemical uptake rate constants for the chemicals tested were ranked in the following order: captan~phenol>aniline>ethanol~ indole ~ trifluralin ~ propanil>1,2,4-trichlorobenzene(TCB)>nitrobenzene~ atrazine>bromacil>simazine>monuron. Thus, captan was taken up more rapidly than the other chemicals studied. Such studies, of course, do not represent uptake of chemicals from soil into whole, intact plants, but they do represent a valid plant/chemical interaction which forms part of the complete system of chemical-plant kinetics, as noted by the authors.

Whole plant uptake studies have been completed with bromocil, phenol, nitrobenzene, captan, butanol 1,3-Di nitro benzene, 2,6-dechlorabenzonitrile, and para-nitrotoluene; and other uptake studies are scheduled. The results of studies for uptake of nitrobenzene and bromacil by hydroponically grown mature soybean plants are discussed in a presentation by McFarlane *et al*. (McF85b). Another report detailed the comparison of chemical fate in plants of 2 herbicides (bromacil and dichlorobenzonitrile) with two industrial chemicals (nitrobenzene and dinitrobenzens) (McF86a).

Related to this plant work was the development of a computer searchable data base on the Uptake, Translocation, Accumulation, and Biodegradation of Organic Chemicals in Plants (UTAB). A description of this data base and its use is in a paper presented at the Annual Plant Physiology meeting in June, 1985 (Va85). This data base was developed as an expansion of a data base, PHYTOTOX, developed at the University of Oklahoma.

Another output from personnel working in Corvallis research was the development of a plant uptake model. This model was described in a paper, "A Mathematical Model of the Bioaccumulation of Xenobiotic Organic Chemicals in Plants," by Boersma et al. (Bo85). The long-range plan is to parameterize this model for various plants and couple it with a soil model to allow prediction of plant uptake on the basis of chemical parameters.

ACQUATIC RESEARCH

The Environmental Research Laboratory, Duluth, MN and the University of Wyoming have been responsible for the work on aquatic toxicity data for synfuels process waters. The emphasis in this cooperative effort has been on aquatic hazard assessment of untreated process waters likely to be discharged, treated process waters, and process water fractions.

Primary and secondary objectives are taken from a research plan by Biesinger, et al. (Bi82):

Primary Objectives:

1. Evaluate the aquatic toxicity of potential untreated discharges from oil shale processing, coal gasification and tar sands extraction, emphasizing mine drainage waters, raw and spent oil shale leachates, and untreated process waters to be discharged to spent oil shale or ash piles.
2. Evaluate the aquatic toxicity of treated process waters from pilot-scale water treatment methods for oil shale processing, coal gasification and tar sands extraction, including retort, condenser, blowdown and air treatment wastewaters.
3. Identify principal toxic fractions and constituents in process waters studied under Objectives 1 and 2 from oil shale processing, coal gasification and tar sands extraction.

Secondary Objectives:

1. Compare chemical and toxicological characteristics of process waters from advanced fossil-fuel processing technologies to determine similarities and differences as a basis for minimizing needs for further toxicology characterization and for simplifying design requirements for treatment technologies.
2. Advance the state-of-the art in aquatic toxicology by comparing results of traditional methods (e.g., 96-hour flow-through acute, embryo-larval, and life cycle tests) with new candidate procedures which may be more sensitive or serve other testing objectives (e.g., pathology, behavior, population - level and community-level tests).

This research plan also presents results obtained, a proposed complex effluent hazard assessment scheme, and a summary of conclusions to date. These conclusions are that:

Oil shale process water toxicities are similar within groups.

Oil shale process water treatment effectiveness varies.

Raw oil shale leachate toxicities vary, depending on shale source.

Oil shale mine waters appear to be non-toxic.

Few data are available on spent oil shale leachates and shale oils.

Underground coal gasification process water toxicities are similar.

Tar sands process waters are less toxic than oil shale and coal conversion process waters.

Hazard assessment protocols are needed for synfuel-related products and waters.

A later report by Bergman and Meyer (Be83) in 1983 summarizes two years of research in aquatic ecosystem effects of process waters produced by synthetic fuel technologies. A major conclusion is that there is a wide variation in the toxicity of various waste waters, and, therefore, each must be evaluated individually. The report also contains some information related to possible treatment methods to reduce toxicity to aquatic animals.

Another aspect of this part of the research has been the development and operation of two information and data storage and retrieval systems. The first is titled AQUIRE for Aquatic Information Retrieval Data Base (Ru84). The objectives of this system were to provide a comprehensive, systematic, computerized compilation of aquatic toxicity data for single compounds, and to analyze toxicity data on sufficient chemicals and organisms to provide comparisons among organisms, chemicals, and test endpoints.

The second data base is named CETIS for Complex Effluents Toxicity Information System (Cr84, Gu84). The objectives of this system parallel those for ACQUIRE except that CETIS deals with complex effluents rather than single compounds.

Both of these data storage and retrieval systems are parts of the much larger data base systems in use by the Environmental Protection Agency. These programs are coded to facilitate ready access to the various data bases which comprise the total system.

VI. ENVIRONMENTAL RISK ASSESSMENT

Environmental risk analysis has been defined as the process of estimating the probability of adverse changes in the environment which are the result of human activities. This is an emerging field and a lot of effort has been directed towards its development during the past decade.

It was looked upon as a potentially important contribution to decision making in a report by Gove et al. in 1983 (Go83). These authors indicated the applications by Federal regulatory agencies of risk data for developing regulatory standards. They also pointed out the usefulness of risk analysis elements being integrated into research when appropriate.

These and other considerations were in mind in establishing the Integrated Environmental and Health Risk Analysis Program for Synfuels. It was envisioned that pertinent information and data could be developed which would be useful to the agency in regulatory decision making.

Hopefully, effluent waste streams from a technology process can be ranked by environmental risk; changes in risk level associated with various control technology options can be estimated; sensitivity of risk estimates to variables which are site dependent can be estimated; and areas where further research could reduce the uncertainty in and further refine estimates of risk can be identified.

Early efforts were directed toward identifying toxicological data, quantifying adverse environmental impacts from synfuels chemicals, developing environmental risk assessment methodology, applying the resulting methodology to specific examples of synfuels technology, and identifying of areas which required additional environmental research.

An early report by Barnthouse et al. (Barn82), which was titled "Methodology for Environmental Risk Assessment of Synfuels Technologies," described the procedures and methodologies planned for the environmental risk assessment for synfuels. Other literature citations regarding the methodology development for environmental risk assessment as well as results from the research are Barn84, Barn85c, Barn86a, Barn1, Barn2, Bart83, Bart84a, ON82, ON83, Su85b, Su1, and Su2.

The efforts were scheduled to cover risk assessment for three synfuels technologies (direct coal liquefaction, indirect coal liquefaction, and shale oil extraction), including five selected environmental endpoints (reductions in fish populations, development of algal populations, reductions in timber yield, reductions in agricultural production, and reductions in wildlife populations), five possible methods for estimating risk (analysis of extrapolation error, quotient method, fault tree analysis, analytic hierarchy process, and ecosystem uncertainty analysis), and comparisons of the results derived from the various methods for risk estimation. These efforts were discussed in detail by Barnthouse et al. (Barn82) and periodically by the ORNL personnel in progress reports, such as (Barn83a) and (Barn84a), which were made to the EPA Project Officer.

The toxicological data base was obtained from the literature and primarily through the various computer data bases which have been developed in recent years by EPA and other organizations. The availability of toxicity data for synfuels chemicals has increased appreciably during the last several years.

Since the United States does not have large-scale synfuels plants in operation, it was necessary to simulate several reference environments in which modeling could be done. The report, "Generic Environments for Synfuels Risk Assessments," by Travis et al. (Tr83) describes in detail the two reference sites selected as well as the alternate site.

Thus, the risk assessments are generic in nature in that they are for the purpose of evaluating risks associated with technologies rather than with those associated with specific plants at particular sites. The report (Tr83) also discusses the near-field and the far-field of each reference site with emphasis on the near-field in which significant concentrations of at least some of the synfuels chemicals might be expected to occur.

The important parameters considered by Travis et al. (Tr 83) in selecting sites for synfuels technologies were an ample source of synfuels stock of satisfactory quality, a reliable and sufficient supply of water of adequate purity, and industrial interest in developing it as a synfuels facility site.

In each case, the physical description (terrain, meteorology, surface and subsurface hydrologies, and vegetation in the region), ecological populations-at-risk (resident aquatic flora and fauna, resident terrestrial flora and fauna, and nonresident members of these groups), and human populations-at-risk (people residing in the region, people who consume water from the region and people using foodstuffs from or derived from the region) are described and discussed for each of the selected reference sites. Various relevant parameters for these sites are contained in several appendices.

The reference site for the oil shale treatment facility is the region of the Green River Formation of northwestern Colorado, southwestern Wyoming, and northeastern Utah. There are large resources of oil shale in this region and the quality of the deposits is quite high. For analogous reasons, the generic environment selected for a coal liquefaction site is the region denoted as the Appalachian Basin. This region is centered in eastern Kentucky and western West Virginia. There is a large and ready supply of coal in the region which is undesirable for many other purposes.

These reference sites, the western one and the eastern one, readily meet the resource and water supply criteria and would seem desirable for large scale industrial development if decisions are made to proceed with an oil shale extraction technology facility or a synfuels plant for coal liquefaction. Perhaps the characteristics of these two reference sites are different as to their physical environments, ecological populations-at-risk, and human populations-at-risk.

An alternate reference site was selected for some synfuels facilities in the Fort Union Basin which is located in northwestern South Dakota, western North Dakota, and eastern Montana. There is an abundance of adequate coal and availability of good water in the region. Again, the characteristics of the physical environment, ecological populations-at-risk, and human populations-at-risk are much different from the two reference sites identified above.

The report by Travis, et al. (Tr83), titled "Exposure Assessment Methodology and Reference Environments for Synfuel Risk Analysis," presents an exposure assessment methodology for evaluating health and environmental risk from synfuels technologies and provides broad characterization for the two reference environments in which synfuels facilities might be sited. Certain modifications in the environmental assessment methodology and its applications are enumerated in this report.

The methodologies include atmospheric, aquatic, and terrestrial food chain pathways, and these are discussed in detail. The atmospheric pathway covers areas up to 50 km and those beyond 250 km from the site. These are well covered by existing models, whereas the main problem area is between 50 and 250 km from the site. The aquatic pathway covers surface and ground waters, whereas the terrestrial system includes drinking water, agricultural produce, beef and milk, and default values regarding site specific parameters.

Reference sites are the same as described in the earlier report by Travis et al. (Tr83). That is, each is described in terms of its physical environment, ecological populations-at-risk, and human populations-at-risk.

The report stresses that the methodologies and parameters are generic and intended only for screening purposes. Assessment methodology is described very well and important details regarding the environmental exposure assessment are given. Obviously, the reference sites are used for assessment as no commercial synfuels facilities are currently operational in the U.S.

A report, ORNL/TM-9070 (Barn85b), provides an analysis for all 38 RAU's (RAC's) when released on a unit basis into the environment. They provide results of a risk analysis study performed for the 38 categories of chemical contaminants that may be released to the environment by synthetic fuels production facilities. They discuss modeling of the environmental transport and fate of contaminants in the atmosphere and in surface water, quantification of risks with respect to the five ecological endpoints in the research protocol, and utilization of the two reference sites.

Using a uniform release rate for comparative purposes, the risk analysis is limited to estimating the relative risks of the various RAU's as functions of their environmental chemistry and toxicology. Tables present the effects on specific endpoints and rank the RAU's accordingly. The rankings were determined by several procedures and differ somewhat in relative values although the rankings are highly correlated.

Barnthouse, et al. (Barn85b) also identified a number of fairly significant uncertainties in their work. The quantification of uncertainties in risk analysis for ecological systems has been addressed by Barnthouse et al. (Barn83b), whereas problems related to ecotoxicity data extrapolation are discussed by Suter et al. (Su84b, Su85a). Toxicological data suitable for use in risk analysis are fairly abundant for fish and relatively sparse for other organisms (Su83). Frequently, the diversity and lack of comparability of the test systems used limit the utility of the existing data. When considering uncertainty in expected environmental concentrations of synfuels chemicals and predicted effects thresholds for fish to synfuels effluents, the uncertainty of the toxicological effects is much greater than that concerning environmental transport (Bart84b, Bart85).

The environmental risks associated with several synfuels technologies are presented in three recent reports, ORNL/TM-9074, "Environmental Risk Analysis for Direct Coal Liquefaction" (Su84a), ORNL/TM-9120, "Environmental Risk Analysis for Indirect Coal Liquefaction" (Barn85a), and ORNL/TM-9808, "Environmental Risk Analysis for Oil from Shale" (Su86). The primary purposes of these reports are to help guide environmental research on synfuels technologies by identifying the most hazardous synfuels chemicals and to determine the most important sources of scientific uncertainty regarding the fate and effects of these synfuels chemicals.

As indicated earlier, the strategy involves grouping the effluent synfuels chemicals into representative groupings, RAU's, utilizing reference sites which have characteristics of sites likely to be selected for commercial synfuels sites, and assessing environmental risks in terms of five specific adverse ecological endpoints; namely reductions in fish populations, timber yield (or undesirable changes in forest composition), agricultural production, and wildlife populations, and development of algal blooms that detract from water use.

A synopsis of each report is taken almost verbatim from the report's summary.

Report ORNL/TM-9074 (Su84a) on direct coal liquefaction contains results of a risk analysis of four direct coal liquefaction technologies: Exxon Donor Solvent (EDS), Solvent Refined Coal-I (SRC-I), Solvent Refined Coal-II (SRC-II), and H-Coal. All four technologies had equal capacities (2.72×10^4 Mg coal/d) and the same waste treatments. All were located in a reference environment resembling eastern Kentucky. Estimates of concentrations of released contaminants in the air, and surface water of the reference environment were obtained, using a simple Gaussian-plume atmospheric dispersion and deposition model and a steady-state surface water fate model. Concentrations in soil and soil solution were obtained from a terrestrial food chain model.

Risk to the five ecological end points were estimated using one or more of three methods: the quotient method, analysis of extrapolation error, and ecosystem uncertainty analysis. In the quotient method, estimated environmental concentrations were compared to toxicological benchmarks such as LC_{50}'s (lethal dose to 50% of the population exposed) available for standard test organisms. In analysis of extrapolation error, statistical relationships between the sensitivities to contaminants of the various taxa of fish and between acute-and chronic-effects concentrations were used to estimate, with appropriate error bounds, chronic-effect thresholds for reference fish species characteristic of the reference environment. Taxonomic extrapolations were used to express the acute effects of RACs in terms of a common unit, the 96-h LC_{50} for largemouth bass. The extrapolated LC_{50}'s and the source-term estimates were then combined and used to assess the acute toxicities of the whole effluents from the four technologies. In ecosystem uncertainty analysis, an aquatic ecosystem model was used to compute risk estimates that explicitly incorporate biological phenomena such as competition and predation that can magnify or offset the direct effects of contaminants on organisms.

With respect to fish, nine RACs were determined to be significant for one or more technologies. RAC 5 (ammonia) was the only RAC found to be significant for all technologies, waste water treatment options and analysis methods. RAC 34 (cadmium) was significant for all technologies and water treatment options according to the quotient method and by all three methods for EDS and H-Coal. The whole effluent from the H-Coal technology with conventional water treatment appeared to be the most acutely toxic. For all technologies, conventional pollutants appear to be more hazardous to fish than the complex organic contaminants usually associated with synfuels.

Algal toxicity data were available for only 10 RACs. Because of the diversity of experimental designs and test end points used in algal bioassays, it was not possible to rank the RACs using the quotient method. However, most of the toxicity quotients calculated for algae were lower than the corresponding quotients for fish. Ecosystem uncertainty analysis suggested greater risks of effects on algae than did the quotient method, primarily because reductions in grazing intensity related to effects of contaminants on zooplankton and fish. Both methods indicate that RAC 21 (phenols) and RAC 34 (cadmium) posed a significant risk to algal communities.

Conventional pollutants, especially SO_2 and NO_2, were found to have the greatest potential effects on terrestrial biota. Ground-level SO_2 concentrations for all technologies were within 1 to 2 orders of magnitude of phytotoxic levels, even excluding background concentrations. Gaseous pollutant levels were well below toxic concentrations for terrestrial mammals; however, it was not possible to assess risks to nonmammalian wildlife (e.g., birds). Of the materials deposited on soil, RACs 31 (arsenic), 33 (nickel), and 34 (cadmium) pose the greatest threat of toxicity. However, observable effects are unlikely unless these trace elements are deposited on soils with high background concentrations and chemical properties favoring the solution phase.

The report on indirect coal liquefaction, ORNL/TM-9120 (Barn85a) contains the risks associated with two indirect coal liquefaction technologies: Lurgi gasification with Fischer-Tropsch synthesis and Koppers-Totzek gasification with Fischer-Tropsch synthesis. The plant configurations evaluated were adapted from design information provided by the developers of the technologies. Both configurations reflect a feed coal capacity of 2.72×10^7 kg (30,000 tons) per day. Source terms for atmospheric and aqueous waste streams were based on published process conceptual designs and test data obtained from bench-scale, pilot, or demonstration units. Control technology efficiencies were extrapolated from similar applications in other industries.

A reference environment resembling eastern Kentucky or West Virginia was employed in the risk analyses. Estimates of concentrations of released contaminants in the air, soil, and surface water of the reference environment, were obtained, using a simple Gaussian-plume atmospheric dispersion and deposition model and a steady-state surface water fate model.

Risk to the five ecological endpoints were estimated using one or more of three techniques: the quotient method, analysis of extrapolation error, and ecosystem uncertainty analysis. In the quotient method, estimated environmental concentrations were simply compared to toxicological benchmarks such as LC_{50}'s available for standard test organisms. In analysis of extrapolation error, statistical relationships between the sensitivities to contaminants of the various taxa of fish and between acute-and chronic-effect concentrations were used to estimate, with appropriate error bounds, chronic-effect thresholds for reference fish species characteristic of the reference environment. Taxonomic extrapolations were used to express the acute effects of all RACs in terms of a common unit, the 96-h LC_{50} for largemouth bass. The extrapolated LC_{50}'s and the source term estimates were then combined and used to assess the acute toxicities of the whole effluents from the two technologies. In ecosystem uncertainty analysis, an aquatic ecosystem model was used to compute risk estimates that explicitly incorporate biological phenomena such as competition and predation, which can magnify or offset the direct effects of contaminants of organisms.

With respect to fish, nine RACs were determined to be significant for one or both technologies. RAC 5 (ammonia) and RAC 34 (cadmium) were the only RACs found to be significant for both technologies and all risk analysis methods. RAC 4 (acid gases) was significant for both technologies, according to the quotient method and analysis of extrapolation error; however, this RAC could not be addressed using ecosystem uncertainty analysis. The whole effluent from the Lurgi-based technology appeared to be somewhat more acutely toxic than the corresponding effluent from the Koppers-Totzek technology. For both technologies, conventional pollutants such as ammonia, cadmium, and hydrogen sulfide appear to be substantially more hazardous to fish than the complex organic contaminants usually associated with synfuels.

Algal toxicity data were available for only ten RACs. Because of the diversity of experimental designs and test endpoints used in algal bioassays, it was not possible to rank the RACs using the quotient method. However, most of the toxicity quotients calculated for algae were lower than the corresponding quotients for fish. Only RACs 33 (nickel) and 34 (cadmium) would be judged significant for any technology using the quotient method. Ecosystem uncertainty analysis suggested greater risks of effects on algae than did the quotient method, primarily because of reductions in grazing intensity related to the effects of contaminants on zooplankton and fish.

Conventional pollutants, especially SO_2 and NO_2, were found to have the greatest potential effects on terrestrial biota. Ground-level SO_2

concentrations for both technologies were within 1 to 2 orders of magnitude of phytotoxic levels, even excluding background concentrations. Gaseous pollutant levels were well below toxic concentrations for terrestrial mammals; however, it was not possible to assess risks to nonmammalian wildlife (e.g., birds). Of the materials deposited on soil, RACs 31 (arsenic), 33 (nickel), and 34 (cadmium) appear of greatest concern for phytotoxicity. However, observable effects are unlikely unless these trace elements are deposited on soils having pre-existing high concentrations of these elements and chemical properties favoring the solution phase.

The third report in this series for oil from shale, ORNL/TM-9808 (Su86) contains results of a risk analysis of the Paraho and TOSCO-II oil shale technologies. The source terms were estimated for commercial-scale operations producing 7.9 and 7.6 x 10^6 L/d of syncrude for Paraho and TOSCO-II, respectively. Because of Colorado State regulations, the plants were assumed to have no direct aqueous discharges. All wastewaters were assumed to be used to wet the spent shale, which is landfilled with other solid wastes. The chemical composition of the leachate from this mixture and its transport to ground and surface water were estimated. Atmospheric emissions were dispersed by a Gaussian-plume model, deposited on the landscape, and accumulated in the soil. The analyses, results, and conclusions of this research are intended to be generic and are not estimates of actual impacts of specific plants at specific sites.

The leachate was less dilute in the creek water than in the nearest well. Creek water contained several RACs in concentrations that exceeded a hundredth of measured toxic concentrations for fish, algae, livestock, wildlife, or irrigated crops. They are benzene, mono/diaromatic hydrocarbons, polycyclic aromatic hydrocarbons, alkaline N heterocyclics, neutral N, O, or S heterocyclics, carboxylic acids, phenolics, nickel, cadmium, and total dissolved solids. All of these categories deserve additional attention in future research and assessments; however, total dissolved solids (TDS) is the category that appears most likely to cause environmental problems because its incremental concentration is quite high (290 mg/L) relative to potentially toxic levels, and because the leachate will enter the Colorado River system where TDS is already a problem for both agriculture and aquatic life.

Of the atmospheric emissions, only SO_2 and NO_2 had predicted concentrations in air that were within a factor of 100 of thresholds for effects on growth or yield of flowering plants. Although these gases are unlikely to reduce crop or range yield at the predicted concentrations, site-specific assessments should consider the effects of rough terrain and background pollution levels on concentrations of these gases. Arsenic was predicted to accumulate in soil to concentrations that were greater than a tenth of those that are reported to reduce plant growth. Future assessments should consider the speciation of the emitted arsenic, transformations in the soil, and background concentrations of toxic trace elements in the soil.

None of the RACs appears to pose a significant threat to wildlife due to inhalation. However, the available data on inhalation toxicology is almost entirely derived from mammals and other taxa, particularly birds that may be considerably more sensitive.

Although they are not considered in this analysis, it appears that construction, mining, and waste disposal are more likely to reduce the productivity of plants and animals than are the emissions from shale processing. Major sources of uncertainty include the composition and transport of leachate from the mixed solid waste and wastewater, effects of accumulation of chemicals in wildlife food chains, effects on nonmammalian wildlife, and effects of terrain on air pollutant concentrations. Useful guidance for evaluating monitoring requirements for a synfuels technology site and for the determination of ranking of supplemental monitoring requirements is given in a recent report by Jones et al. (Jo86).

The final report from the ORNL group, "User's Manual for Ecological Risk Assessment," by Barnthouse et al. (Barn86b), is its most important product. This methodology, developed for use in the synfuels environmental risk assessment, can be applied to many other types of assessments. The User's Manual presents the rationale for the synfuels assessments, describes the derivation and mechanics of the three techniques used in those assessments of synfuels risks, and discusses the limitations and other potential applications of ecological risk assessment methods.

VII. HEALTH ASSESSMENT

It was, of course, recognized that synfuels technologies would produce a multitude of chemical products some of which could have adverse effects on biological systems, including people. Therefore, it was necessary to evaluate these chemical entities to determine those which were harmful, at what levels, and under what conditions.

Test procedures using a variety of biological end points were studied. For convenience, these can be divided into relatively short-term screening studies and those of long-term duration which usually are more definitive, more resource intensive, and require longer to evaluate.

The short-term screening tests included *in vitro* assays using various species and strains of bacteria for the detection of toxicity, mutations, and chromosome damage and recombination. Similar assays have detected toxicity, mutation, cell transformation, and chromosome damage utilizing cultured mammalian cells as the test organism.

Health studies of a long-term nature have used whole animals, especially rodents, to evaluate reproductive effects, skin carcinogenicity, inhalation toxicology, neurobehavioral toxicology, and teratology and developmental toxicology.

We have also used direct observation of humans and human-health-records to determine biological effects of synfuels technologies. These clinical and epidemiological procedures can be used when a population or worker group has been exposed to relatively high levels of contaminants and is available for direct or indirect study. Occupationally exposed groups fit into these categories as do certain populations that live in the areas adjacent to synfuels facilities which impact the surrounding environs from discharges of synfuels chemicals.

A complicating factor in health effects as well as environmental effect studies is that no actual synfuels by products and environmental emissions from commercial synfuels technologies facilities are readily available in the United States for evaluation. Therefore, products from a few pilot plants can be studied, and simulated effluents can be made and used on a surrogate basis. These procedures inherently introduce uncertainties into the bioeffects and environmental effects studies.

The actual effluents from synfuels technologies depend on the nature of the resource material, the technology employed, a variety of process parameters, the number and nature of any control procedures, and various features which are site specific. These are desirable problems when one considers the luxury of evaluating a complex energy technology from an environmental protection standpoint prior to its introduction into our industrial society.

The opportunity is thus available to perform health and environmental risk assessments on synfuels technologies during the very early formative and design stages of the technology development. This should be effective in that guidance and any needed controls can be identified early on and used to moderate plant design and operation. The process should be much more effective than waiting for plant design and construction or regulatory pressures based on immediate need.

Information and data on health effects of synfuels chemicals have been presented at a series of annual symposia hosted by Oak Ridge National Laboratory (Co80, Co84). These symposia have included many other aspects of synfuels technologies such as the engineering, chemical characterization, environmental transport and effects, occupational health, and control technologies.

The first of these symposia, "Synthetic Fossil Fuel Technology, Potential Health and Environmental Effects" was held in 1978, and the proceedings were published in 1980 (Co80). Seven papers at this symposium were devoted to biological effects studies and ranged from short-term mutagenicity studies using bacteria to studies using rabbits and mice to evaluate the toxicological and carcinogenic effects of shale oil products. In many of these studies, as well as others, positive results have been observed on the induction of adverse biological effects in the study species.

The proceedings of the 1982 Fifth Life Sciences Symposium, titled "Synthetic Fossil Fuel Technologies, Results of Health and Environmental Studies," was published in 1984 (Co84). There were eight papers devoted to subjects identified in the proceedings as "Toxicology and Transport, Transformation, and Fate". Many of these papers involved <u>in vivo</u> studies whereas Morris, <u>et al</u>. (Mor84c) addressed the use of comparative approaches in extrapolation to health risk. Four papers were based on research supported and sponsored by the Integrated Health and Environmental Risk Analysis Program for Synfuels (Co 84).

A good summary of the bioeffects of synfuels has been published by Rom and Archer (Ro80) as "Health Implications of New Energy Technologies". They address such areas as coal workers pneumoconiosis and respiratory disease, effects from coal liquefaction, and studies related to the production of liquid fuels from shale oil. There are many adverse health effects which have been noticed and documented.

Health experience from these and other health effects studies needs to be carefully reviewed and evaluated in order that steps can be taken in technology development to:

1. Help assure adequate worker protection.
2. Prioritize and select for further development those processes that present minimal or controllable carcinogenic hazards.
3. Insure the incorporation of adequate engineering control measures in plant design as operational procedures.

Many other literature citations can be found which deal with health effects studies of synfuels chemicals. Representative ones include an early review of potential impacts of oil shale technology by Slawson and Yen (Sl80), an article titled "Health Hazards and Pollution" (No80) which deals with chemicals from a coal liquefaction plant, toxicological assessment of refined shale oil using short-term microbial testing by Roa _et al_. (Ro81), a paper by Timourian _et al_. (Ti81) which deals with _in vitro_ and _in vivo_ testing of shale oil products using tests of comparative mammalian genetic toxicology (this test indicates that carcinogenicity decreases after hydrotreating and that since cytogenetic endpoints can be measured *in vitro*, *in vivo*, and in man this test can be used to relate test data to human exposure), and the article by Gray (Gr83) which reviews the research conducted on health and environmental effects of selected synfuels by Pacific Northwest Laboratories.

Health effects research has effectively demonstrated that various effluents from the several proposed synfuels technologies can cause a wide variety of detrimental biological effects. These results can be used for guidance in future technology planning as to priorities, control schemes, and evaluation systems.

The framework to accomplish a comprehensive evaluation of synfuels technologies as well as a comparison of their relative merits is risk assessment. This tool in terms of environmental risk assessment and health risk assessment will be reviewed as to its current status and applicability.

VIII. INTEGRATED HEALTH RISK ASSESSMENT

The health risk assessment aspects of the program were the responsibility of personnel at the Brookhaven National Laboratory (BNL) within the Biomedical and Environmental Assessment Division. The major goal was to assess the health risks associated with synfuels technologies. The research was not in direct support of regulatory development for synfuels, although it was recognized and appreciated that the assessments might at some future time be the basis for regulatory actions.

Program focus from the beginning was on a variety of media; i.e., considerations of concentrations of synfuels chemicals introduced into various environmental media. There were expectations that the synfuels program would be a good place to explore and employ integrated assessment on a pilot basis, and that this, in turn, might chart a similar course for the EPA to move towards consideration of integrated risk in its regulatory policy. At the time, the agency was media oriented and thus separately working with air, water, and solid wastes.

Potential health effects from synfuels chemicals cover a rather broad spectrum. However, perhaps the major concern of most people and many agencies is the induction of cancer. For this reason, the initial focus of the work at the BNL was on cancer induction in humans.

In the report BNL 51783 (Kr83), Kramer *et al*. describe and discuss the full range of health impacts associated with synfuels chemicals. The report reviews the literature for human health effects for each of the thirty-eight Risk Assessment Categories. Later, this report was completely updated.

The health risk assessment was broken down into hazard identification, dose-response assessment, exposure assessment, and risk characterization (NAS83). Such assessments can then be used by decision-makers in establishing regulatory options and in making decisions regarding allocation of priorities and research funding (Mor85c). Several recent reports review the background methodology, laws, and regulations related to cancer risk assessment (OTA81, OSTP84). Also, Anderson et al. (An83) described and discussed applications of quantitative risk analysis in the systematic process of deciding appropriate public policy.

Good estimates of cancer risks from synfuels chemicals was one aim of the BNL research team were efforts to define the uncertainty of those estimates. Therefore, a number of alternate models were set up to explore the uncertainty by observing the differences among models (Mor84b). Also discussed in this article by Morris et al. were a workable definition of health risk assessment, its applications, a step-by-step analysis of its principal components (hazard identification, dose-response assessment, exposure assessment, and risk characterization), and a concise summary of cancer biology.

An important activity was the extensive and comprehensive effort to review the literature to identify and characterize the input data needed to run the several selected models. In this process, lists of chemicals by

RAC were developed; the biomedical literature was searched for studies performed on those chemicals; results were then screened; and pertinent reports were selected for analysis.

The research programs' first analysis was for "unit effects" of selected synfuels chemicals using the six predictive models. These models, described by Morris, et al. (Mor84b), include three statistical models, probit, logit, and Weibull, and three stochastic models, one-hit, multi-hit, and multi-stage.

Results from this first analysis are contained in a draft report (Mor83) which was prepared for the EPA in May 1983. The report was titled "Cancer Risks from Unit Exposure to Chemical Risk Assessment Categories: A Data Base and Preliminary Application" and authored by Morris, et al. The use of unit effects was necessary because the final emission rates for each RAC to be applied for each of the synfuels technologies had not been determined and thus, there were no exposure estimates for specific synfuels technologies.

Unit effects applications also served to exercise the models and identify some of the weak points in the analysis and were useful in addressing questions of trade-off between air and water emissions of synfuels chemicals. These efforts were closely coordinated with the environmental assessment work at the ORNL and resulted in the production of population exposure estimates by RAC and by the selected pathways; namely air, water, and food chains. Exposure estimates were then coupled with the unit effects estimates to yield cancer risk ranges for each selected synfuels technology.

Moskowitz, et al. (Mos85) address potential tumor risks to public health from synthetic-fuel plants. The two plants selected for study were a direct liquefaction-Exxon Doner Solvent-and an indirect liquefaction-Lurgi-Fischer-Tropsch which were located at a representative site in the eastern United States. For these analyses, gaseous and aqueous waste streams were characterized, and the exposures modeled included those from inhalation, terrestrial and aquatic food chains, and drinking water supplies. The analysis suggested that emissions of polycyclic aromatic hydrocarbons, aromatic amines, neutral N, O, S, heterocyclics, nitriles, and other trace elements pose the largest quantifiable risks to public health. The authors point out several pertinent areas which need additional development to improve the model results.

Throughout this research effort, progress was reported in the literature and through various workshops and meetings which included EPA-organized peer reviews and users' meetings.

Some of the more formal presentations which were made by members of the research team from BNL are:

July 6-7, 1982	Workshop on Risks from Mixtures of Chemicals, Harvard University, "Comparisons of Ratio Determinations of Carcinogenicity," H. Fischer and "When More Than Additive is Less than Synergistic," J. Nagy.

September 7-9, 1982	Workshop on Problem Areas Associated with Developing Carcinogen Guidelines, Brookhaven National Laboratory, "Definitions of (Cancer) Potency," H. Fischer, Proceedings of Workshop were published as BNL 51779 (BNL84).
October 24-27, 1982	Fifth Life ORNL Sciences Symposium, Gatlinburg, TN, "Extrapolation to Health Risk: Use of Comparative Approaches," S. C. Morris. The Proceedings of this Symposium were edited by Ken Cowser and published in 1984 (Co84).
November 6-9, 1983	ORSA/TIMS Meeting, Orlando, FL, "Estimating Potential Environmental Cancer Induction from Proposed Synthetic Fuel Plants," S. C. Morris (Mor85c).
April 20, 1984	Brookhaven National Laboratory, Applied Mathematics Department Seminar, BNL, Upton, NY, "Estimating Cancer Risks from Environmental Emissions of Complex Technologies," S. C. Morris. Published as "Estimating Cancer Risk From Complex Technologies: A Users' Manual," S. C. Morris, et al., BNL 37220, October, 1985.
September 30-October 3, 1984	Society for Risk Analysis Meeting, Knoxville, TN, "Treatment of Uncertainty in Cancer Risk Analysis," S. C. Morris, et al.

October 20 - 24, 1985	Twenty-Fourth Hanford Life Sciences Symposium, Health and Environmental Research on Complex Organic Mixtures, Richland, WA, "Epidemiological Bases for Assessing Health Effects of Exposure to Complex Organic Mixtures: Need for Evaluation," Samuel C. Morris. Published in October 1985 as BNL 37307 (Mor85b).

The Users' Manual, BNL 37220, (Mor85c), produced by the research group at BNL, summarizes their work on this project and provides the necessary information to use these methods in extension of this program or in other suitable applications. Emphasis is on potential effluent discharges from synfuels plants to air, water, and food chains. However, the developed methodology is applicable to any technology.

IX. USER REVIEW MEETINGS

In order to establish and maintain effective communication between the synfuels research program and the potential users of the knowledge to plan, institute, and operate a regulatory program for synfuels, a system was set up to periodically hold Users Review Meetings.

These Users Review Meetings basically brought together the EPA Project Officer, the various members of research groups, and the EPA officials representing the components of the Agency which would be involved in developing and implementing a regulatory control program. Representatives from the EPA Headquarters as well as its Regional Offices participated.

Three Users Review Meetings were held. These occurred November 4-5, 1981, September 23-24, 1982, and December 14-16, 1983, in Washington, D.C. Two-way communications were continued between these special meetings by telephone, personal contacts, the exchange of correspondence, and dissemination of reports and other technical documents.

The process served to provide practical and timely input into the research programs and concurrently inform the users of the status, form, and nature of the research efforts as well as the plans for the future. These efforts were effective and mutually beneficial.

X. WORKSHOPS

In the course of the EPA Integrated Health and Environmental Risk Analysis Program for Synfuels, two workshops were held involving experts in risk analysis and those engaged in particular modeling efforts. The first was held in Atlanta, GA in January, 1983, and was titled "A Workshop on Water Modeling Needs and Available Techniques for Synfuels Risk Assessment" (Do83). A second workshop, "Workshop on Food-Chain Modeling for Risk Analysis," was held in Washington, D.C. in March, 1983 (Br85).

The emphasis of the first workshop was limited to available "water models". These are models for runoff, surface water, and soil/groundwater which are capable of predicting chemical migration and fate. The characterization of the current approach to synfuels risk assessment led to an identification of the current needs of risk analysis for water models. The principal need is for relatively simple models/techniques that provide estimates of environmental exposure concentrations with an acceptable level of uncertainty.

Of course, if a simple model does not provide the type of information and statistical characterization needed, it is necessary to proceed to more complex models if these are available for application. The workshop participants addressed this issue by contributing to the development of a hierarchy of different levels of available models/techniques, ranging from the simplest possible techniques to the most sophisticated models.

Particular models/techniques for each level of the hierarchy were identified, along with a characterization of the modes of transport, transfer, and transformation processes that are considered, and the usually expected uncertainty levels.

The goals of the workshop and the conclusions reached by the participants are taken from Donigan and Brown (Do83). The three stated goals were to:

1. Have those currently performing synfuels-related risk assessments describe their needs for models to predict chemical migration and fate in hydrologic systems.
2. Have those currently involved in the development, testing and application of such models respond to these needs by discussing the capabilities and limitations of current state-of-the art water quality and chemical fate models.
3. Provide an overview of the current potential use of water models for conducting risk analysis of chemical releases associated with synfuel technologies.

Presentations and discussions by participants at the workshop indicated that there is a wide variety of water models available for use which range from simple dilution type calculations, through those which may consider advection, dispersion, sorption, volatilization, hydrolysis, photolysis, and biodegradation, to those detailed, site-specific models/techniques which generally consider all the key transport, transfer, and transformation processes. Complex models provide higher resolution in space and time, and generally higher accuracy; however, they require a higher level of resource commitment for use.

Conclusions reached include the following:

1. At the present time, risk analysis is primarily comprised of screening level evaluations of alternative technologies, sites, exposure pathways and pollution control options, as opposed to site-specific evaluations of proposed facilities.
2. Evaluations are performed to identify information gaps, research needs, and needed regulations.
3. Resource and time constraints often limit the level of effort that can be devoted to the analysis of exposure levels.
4. Expected/allowable risk uncertainties are in the range of one to three orders of magnitude.
5. Because of the complexity of synfuels emissions, the risk analysis evaluates exposure and effects of categories of pollutants, as opposed to specific compounds. The use of representative compounds within each category (RAU) is the procedure, amenable to modeling, currently being utilized.
6. The characterization of expected emissions (i.e. the source term) involves significant uncertainties due to the lack of existing commercial scale synfuel facilities.

7. The exposure analysis is concerned with water-related migration and fate of contaminants contained in both potential point and nonpoint source discharges to waterbodies, and leachates generated by solid wastes and raw materials storage areas.

The second workshop focused on the terrestrial and aquatic food-chain models currently utilized in the process of risk assessment. To put these in perspective, Figure 3, from Breck and Baes (Br85), presents the components of the human health risk assessment methodology for synfuels technologies and shows the relationships of the aquatic and terrestrial food-chain transport with the other major parts of the overall process. Thus, in moving from the synfuel pollution source to the assessment of health risk to man, use is made of atmospheric and aquatic transport models, aquatic and terrestrial food-chain transport models, and models that estimate risks from calculated environmental exposures to synfuels chemicals (dose-response models).

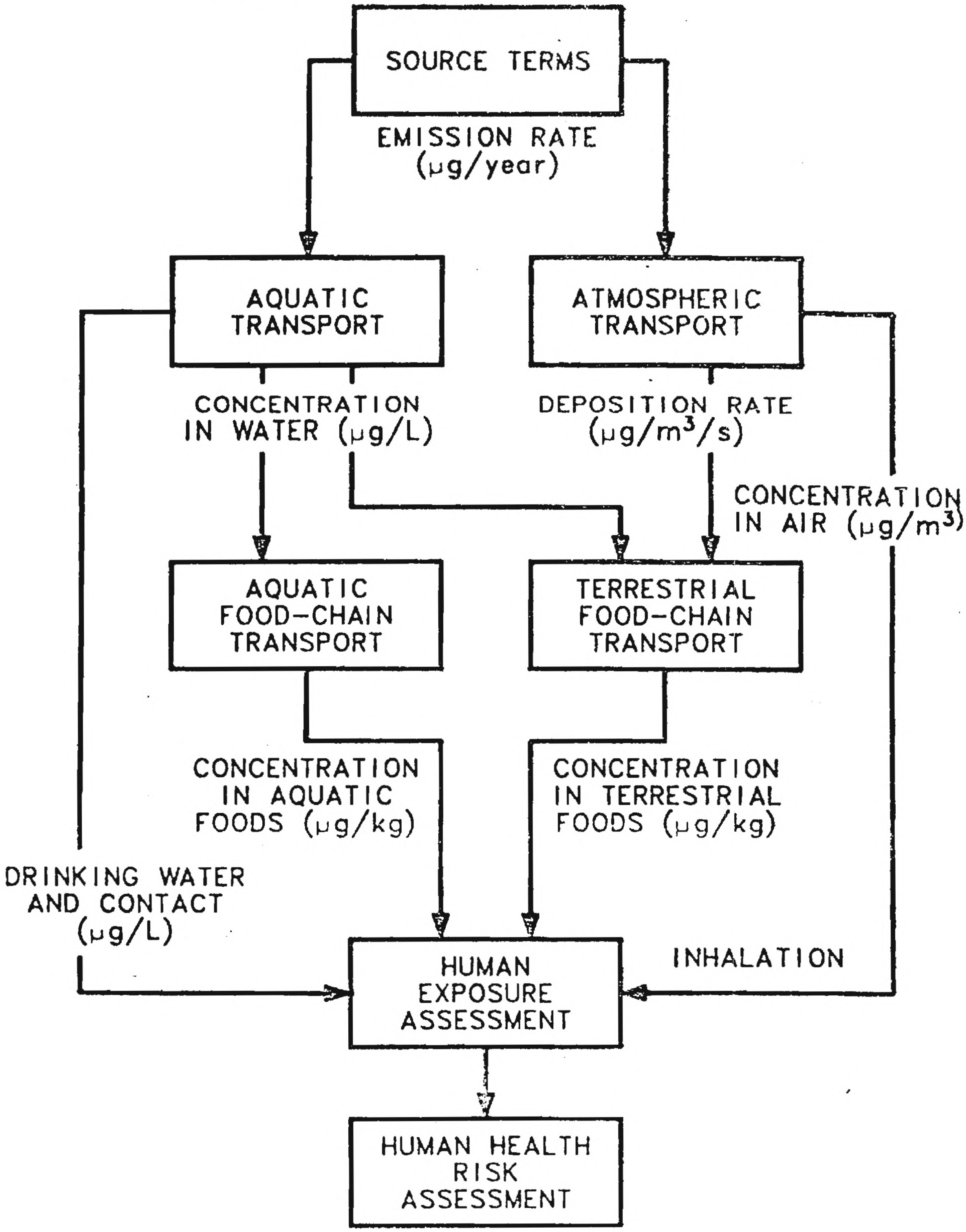
Objectives of the workshop were to obtain the recommendations of experts on:

1. Terrestrial and aquatic food-chain models best suited to synfuels risk analysis.
2. Data sources and parameter estimation methods best suited to synfuels risk analysis.
3. Major limitations on existing data and methods.

FIGURE 3

COMPONENTS OF THE OVERALL HUMAN HEALTH RISK

ASSESSMENT METHODOLOGY FOR SYNFUELS TECHNOLOGIES



Conclusions and major observations of the workshop participants included the following:

1. A simple concentration factor approach is appropriate in aquatic food-chain modeling of chronic low-level releases of synfuels effluents.
2. In terrestrial food-chain models there is a need for greater model complexity to account for location-specific variations in agricultural practice (of course, concentration factors can be used to estimate terrestrial transport).

3. For aquatic and terrestrial models, field data are the best basis for estimating concentration factors. When field data are not available, laboratory data can be used. If no data exist for a particular compound or class of compounds, estimates can be made using partition coefficients based on structure-activity relationships.
4. There exists a need to estimate the uncertainty associated with particular model output.
5. The terrestrial food-chain model needs to include a consideration of a good contamination pathway via foliar absorption and translocation to edible produce parts.
6. The model should consider use of soil degradation kinetics which may be predicted from structure/activity relationships. These would be discerned from examination of the pesticide data base.
7. The model should consider using a prediction of the synfuel compound concentration in the soil solution. This would allow the prediction of the traditional soil/plant concentration factor from hydroponic data and provide a means for assessing the impact of synfuels compounds on crops.
8. A careful consideration of the effects of food processing (especially cooking) on human exposures should improve the model.
9. Consideration of several additional areas which need to be included to define the food-chain model:
   a. inclusion of animal products other than beef and milk

b. accounting for differences in transfer coefficients resulting from livestock management practices

c. water and soil ingestion by livestock (in addition to food)

d. addition of irrigation water as a source term

e. capability to model acute exposures and sensitive populations

f. estimation of uncertainty associated with model predictions

10. Validation is the method not only to ensure that the assessment model is both appropriate and accurate but also to specify definitively the uncertainty associated with model predictions.

XI. PEER REVIEW

The Peer Review process has been used extensively in the U.S. Environmental Protection Agency and is, in essence, an integral part of scientific research. The Integrated Health and Environmental Risk Analysis Program for Synfuels utilized this important process as an essential and continuing function of its research efforts. Not only was the overall program reviewed periodically but also individual peer reviews were conducted on major program elements.

Peer Review Groups were established from time to time to review the entire program and were populated by outstanding experts in the field. Although members varied, there was always continuity represented by several individuals.

In an analogous manner, Peer Review Panels were formed to review major components of the programs such as Health Effects, Food-Chain, etc. These panels were usually smaller than the Peer Review Group and frequently had a member of the group as a participant in its review and evaluation.

Peer Review Groups and Peer Review Panels usually met for one to two days and produced a draft report at the conclusion of each meeting. This was followed up by submission of a final report submitted by the chairman to the EPA Project Officer on behalf of the members.

These meetings were preceded by the reading of pertinent reports and other written material. At the meetings, which were held at strategic locations, the group or panel was briefed by the individual researchers in accord with a predetermined agenda. There was discussion and interaction between researchers and peer reviewers. The procedure was then concluded by an executive session of the peer reviewers in which a draft report was formulated for prompt delivery to the EPA Project Officer. This was promptly followed by submission of the final peer review report.

In addition to the peer review members and the pertinent researchers, these meetings were attended by EPA program officials, the EPA Project Officer, users from relevant EPA organizational components, the Peer Review Group Executive Director, and small numbers of interested observers.

The users are of special importance as these were representatives from the EPA offices which would be involved in establishing and implementing a regulatory program for synfuels technologies.

The schedule of the various peer review meetings and other relevant information are presented in Figure 4, whereas pertinent detail on the composition of the Peer Review Groups and Peer Review Panels and their reports are included in Section XIV, Appendix.

This was an extremely important and useful procedure as it effectively helped guide the research and made numerous, beneficial suggestions and recommendations which were incorporated into the several scientific research efforts.

FIGURE 4

MEETINGS OF PEER REVIEW GROUPS AND PANELS

IDENTIFICATION	CHAIRMAN	DATES	LOCATION
Peer Review Group	Dr. N. C. Rasmussen	Nov. 18-19, 1981	Knoxville, TN
Peer Review Panel on Human Health Effects	Dr. A. C. Upton	May 6, 1982	Brookhaven National Laboratory, Upton, NY
Peer Review Panel on the Food-Chain	Dr. B. E. Vaughan	May 18, 1982	Comparative Animal Research Laboratory, Oak Ridge, TN
Peer Review Group	Dr. S. M. Greenfield	March 29-30, 1983	Alexandria, VA
Peer Review Panel on the Food-Chain	Dr. M. W. Carter	Oct. 27-28, 1983	Environmental Research Laboratory, Corvallis, OR
Peer Review Panel on Kosovo Study	Dr. J. Whittenburger	Nov. 9, 1984	Brookhaven National Laboratory, Upton, NY

XII. CONCLUSIONS

This Section presents in concise form the major conclusions which have been derived from the research conducted under the EPA Integrated Health and Environmental Risk Analysis Program for Synfuels. Other conclusions and various technical and scientific decisions are included in the text.

1. There are several raw materials, available in abundance, from which synfuels can be produced by a number of synfuels technologies. These technologies are producing synfuels in a number of countries whereas they are mainly in the pilot-plant stage in the United States with the exception of the Great Plains Coal Gasification project in Beulah, ND.
2. When synfuels technologies are developed for commercial operation in the United States, there will be a concurrent requirement for environmental and health protection programs to ensure protection, have environmental acceptability, assure a high degree of meeting regulatory requirements, and put in place a plan to monitor environmental and health related emissions.
3. A comprehensive evaluation of synfuels requires assessment of the occupational workers during the technology conversion process, the health and environmental effects from synfuels technologies, and the health and environmental effects from the uses of synfuels.
4. There is such a variety of complex chemicals associated with synfuels that it is necessary to establish a manageable system to deal with this wide spectrum of materials. The Risk Assessment Category (Risk Assessment Unit), consisting of some 38 categories of materials, was established for this purpose.

5. The approach taken to produce needed field and laboratory data to provide needed input into the risk analysis of health and environmental effects of synfuels was effective. Thus, laboratory and field research was integrated into the assessment models utilized for the evaluation of health and environmental effects.
6. There are a number of benefits which can be derived from having a close cooperative working relationship between two similar Federal agency programs. This type effective agreement was maintained between the U. S. Department of Energy Health and Environmental Assessment Program and the Integrated Health and Environmental Risk Analysis Program for Synfuels.
7. The occupational assessment of a surrogate study group, the coke oven workers, supplied useful information as to the protocols and procedures needed to effectively evaluate synfuels workers and technologies.
8. The Kosovo Coal Gasification Plants' work atmospheres are extremely variable. Samples from personnel are the only way to obtain meaningful exposure results and even then care must be taken when these results are interpreted as representative of a job classification or a group of workers performing the same job.
9. The occupational health evaluation of the Kosovo coal gasification plant workers shows that worker exposures to a wide variety of coal gasification airborne workplace contaminants are usually below occupational exposure limits such as the guidelines of the American Conference of Governmental Industrial Hygienists.

10. A number of chemicals, representative of particular RAU/RAC, are readily transferred to and found in various edible animal products such as milk, eggs, and meat.

11. Hydroponic system results indicate a transfer of many synfuels chemicals (representative of RAU/RAC) into plants.

12. Research in aquatic ecosystem effects of process waters produced by synfuels technologies shows a very wide variation in the toxicity of various waste waters.

13. Risk analysis is a valuable and useful methodology in the understanding and evaluation of environmental and health effects of synfuels. It will be an effective tool in the regulatory decision making process.

14. The availability of toxicity data for synfuels has increased appreciably during the last several years and this research program contributed appreciably to this data base.

15. The concept of using generic environments for synfuels risk assessments is useful, since commercial synfuels technologies are not in operation in the United States.

16. Specific adverse ecological endpoints have been developed and quantified for use in the assessment of environmental risks.

17. The User's Manual for Ecological Risk Assessment presents the only risk assessment methodology available for the effects of synfuels on non-human biota, and this methodology can be applied to other types of environmental contaminants.

18. The opportunity to study and evaluate health and environmental effects of synfuels, prior to large-scale use of synfuels technologies on a commercial basis in the United States, is recognized as a real advantage.

19. There is a variety of short-term screening tests, such as in vitro assays using bacteria and cultured mammalian cells to detect toxicity, mutations, chromosome damage, and recombination, as well as long-term studies using whole animals to evaluate reproductive effects, inhalation toxicology, skin carcinogenicity, neurobehavioral toxicology, and teratology and developmental toxicology, available for assessing biological and health effects of synfuels.

20. Six predictive models, including three statistical and three stochastic models, were used to evaluate health effects and the uncertainties associated with them for "unit discharges" from synfuels technologies.

21. The several predictive models were utilized to produce population exposure estimates by Risk Assessment Category and by selected pathways, namely air, water, and food chains, for effluents from various synfuels technologies.

22. The Users Manual produced by Brookhaven National Laboratory, BNL 373220, summarizes health effects research and provides necessary information to use the developed technology in extension of synfuels work or in other appropriate assessments of different technologies.

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XIV. APPENDIX

Report of the Peer Review Group for the Integrated Health and Environmental Risk Analysis Program.

Report of the Peer Review Panel on Human Effects of Synfuel Production.

Report of the Peer Review Panel on the Food Chain Transport of Synfuels.

Report of the Peer Review Group on the Integrated Health and Environmental Risk Analysis Program for Synfuels.

Report of the Peer Review Panel on the Food Chain Transport of Synfuels.

Report of the Peer Review Panel on Human Health Effects of Exposure in a Coal Gasification Plant.

These reports have been retyped for inclusion in this Report. The purpose was to make the formats more consistent.